Detection of the emission of the particles from a free surface of metals loaded by strong shock wave using the Synchrotron Radiation methods.

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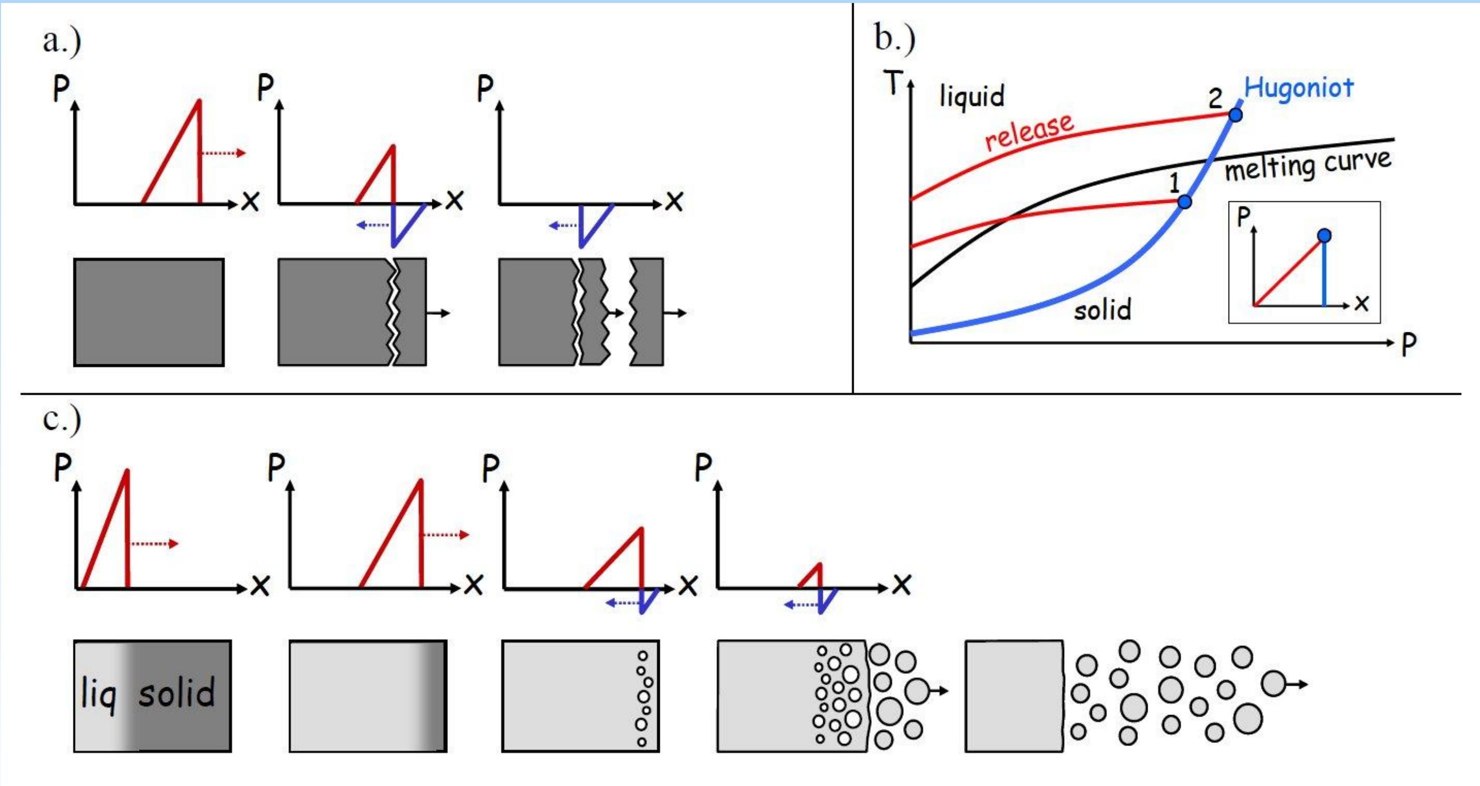
Actuality of the problem of registration of micro and nanoparticles.

1. *High speed projectiles are required to obtain ultra-high settings.*
2. *The effectiveness of compression materials decreases strongly due to the appearance in front of the striker flow microparticles (dust).*
3. *Existing registration techniques can detect the microparticle size of about 3-5 microns.*
4. *Currently, only the dynamic diffraction techniques with synchrotron radiation can detect the presence of nanoparticles.*

Causes of "dusting".



a) breakaway in solid bodies, b) P-T diagram of tin melting, c) dusting in liquids

Review of work on "dusting".

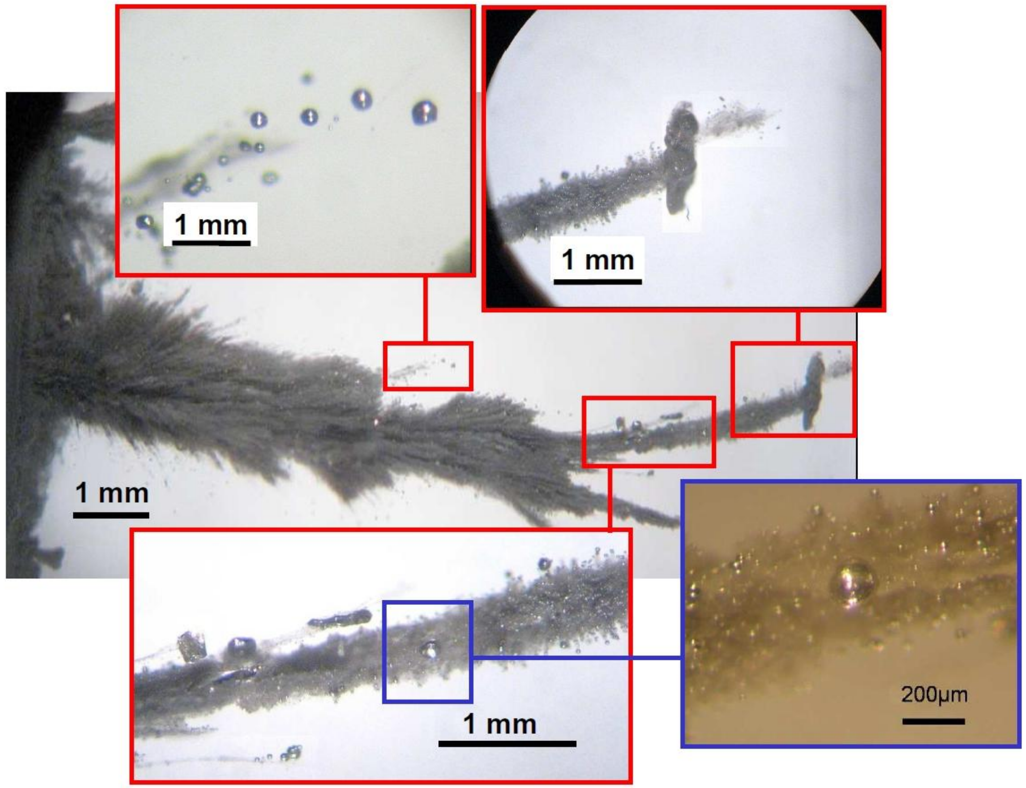


Fig. 6. Optical micrographs of fragments collected in gel set behind the free surface of laser shock-loaded tin target (Test 6).

Features of optical registration. France, 2010

Review of work on "dusting".

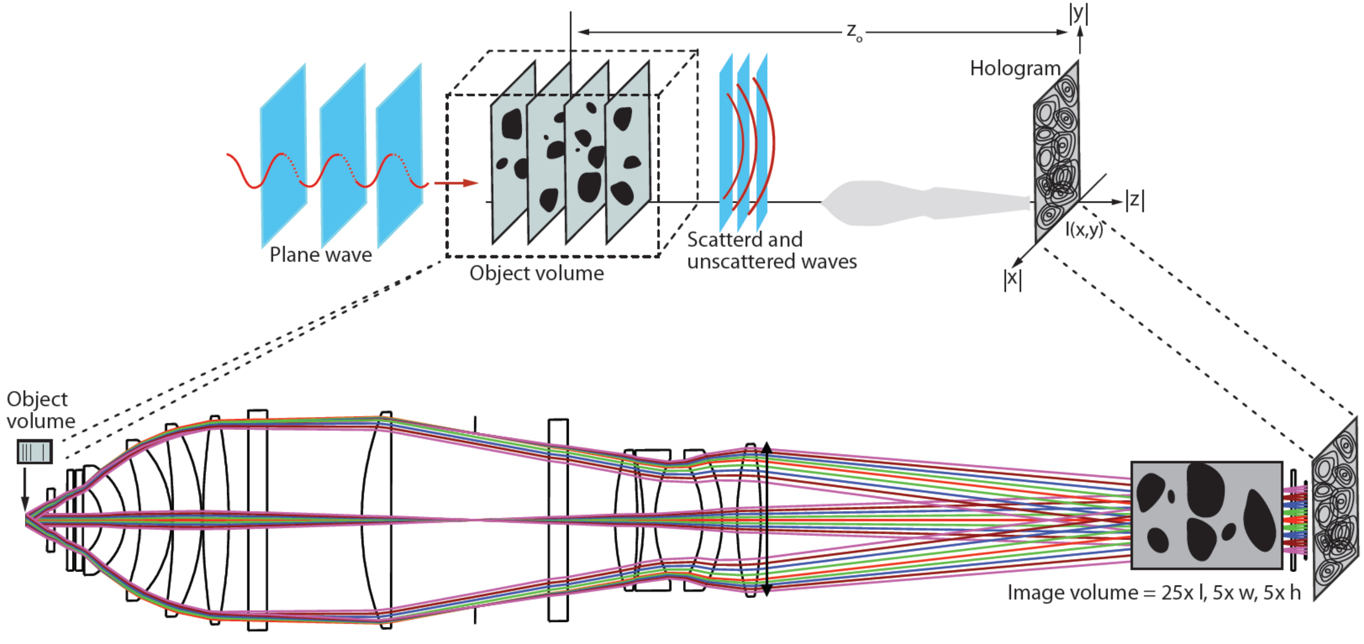
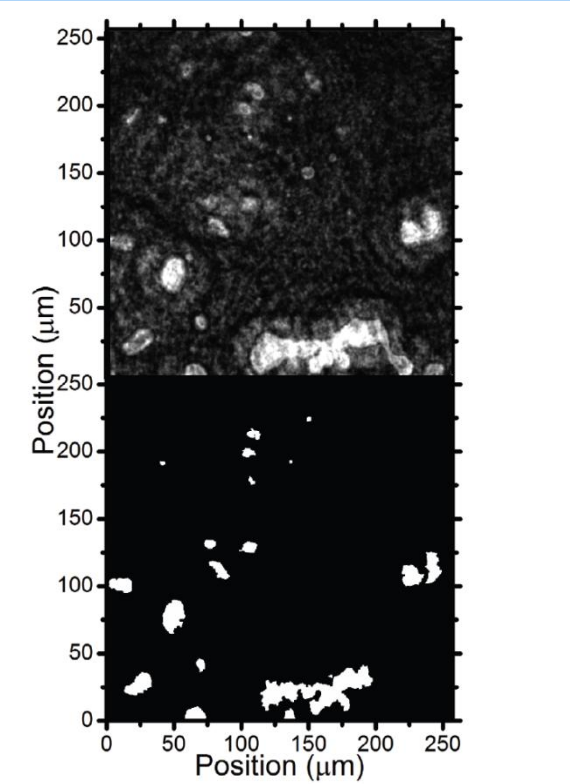


Fig. 2.1.2. The in-line Fraunhofer technique is adapted to be used to measure particles in a dynamic shock physics expeirment. A high-resolution lens system is located just after the object volumen as illustrated in the figure. The lens system relays the scattered and unscattered wavefronts some distance from the high-explosive experiment to where the hologram can be formed without being damaged. The lower part of the figure shows the lens system and the object volumen being relayed with magnification of 5 to a location just in front of the film.

Fraunhofer Holography in LNL, 2013

Review of work on "dusting".



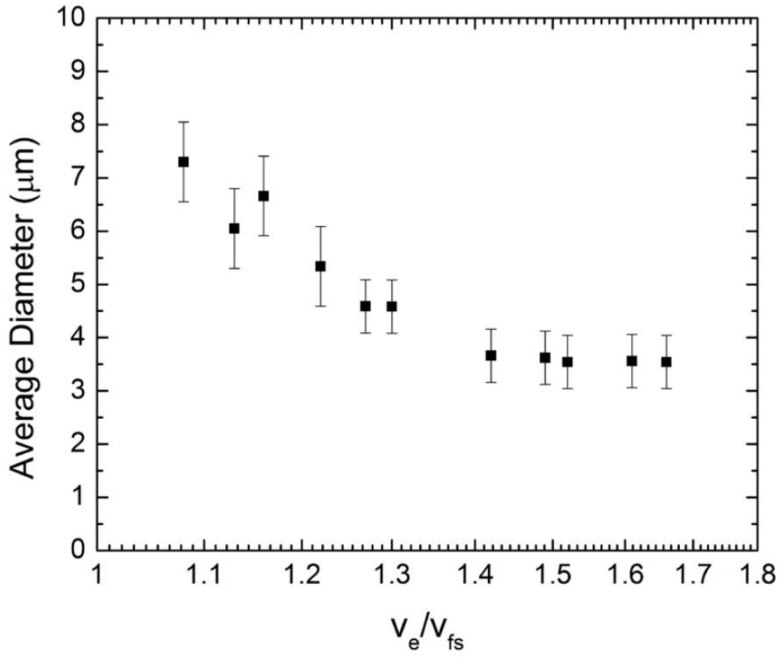
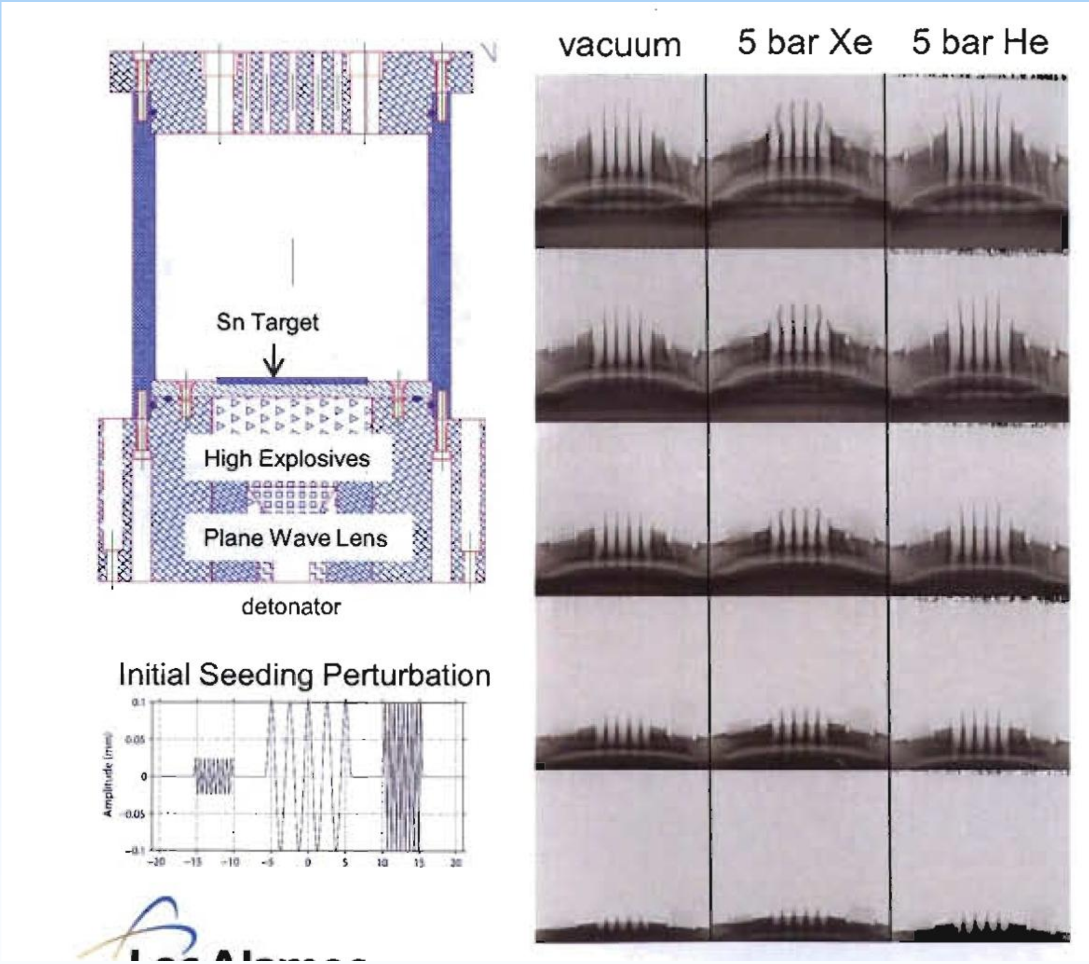


Fig. 3.1.6. The average partice diameter as a function of ejecta velocity.

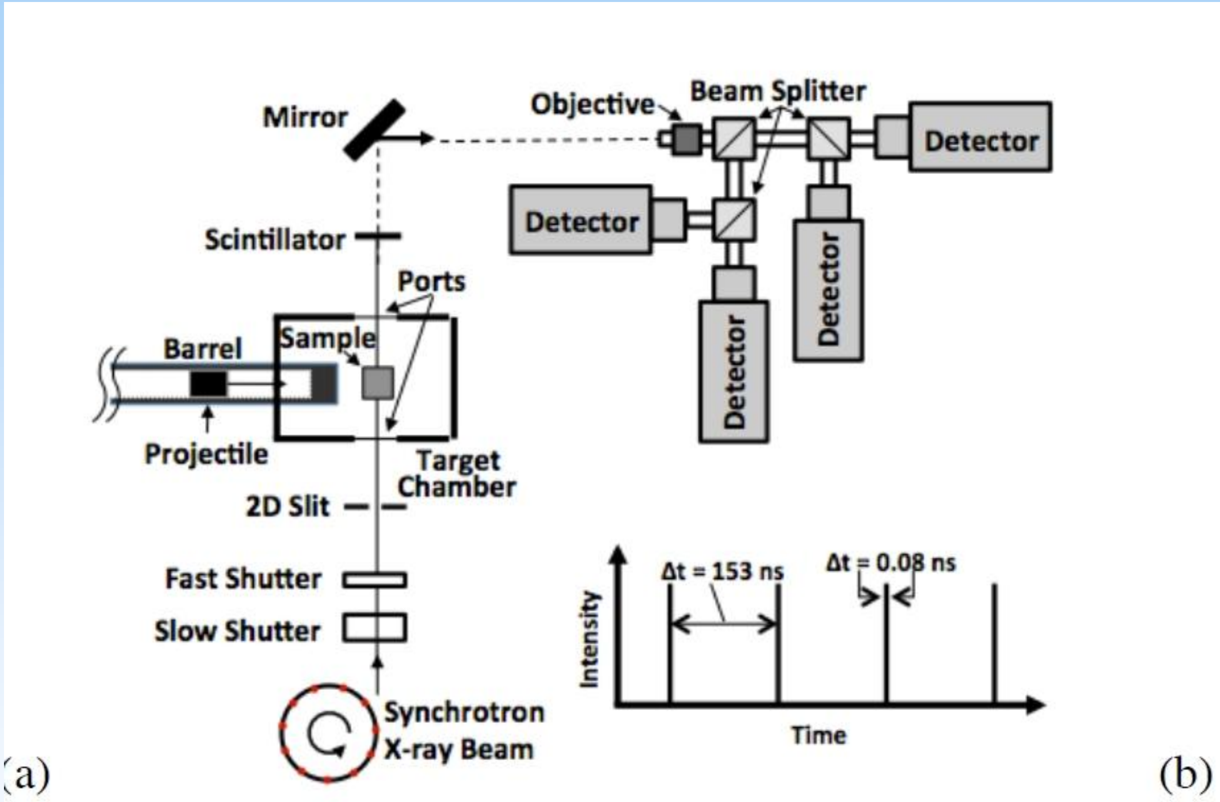
Ultraviolet In-Line Fraunhofer Holography in LNL

Review of work on "dusting".



Proton diagnostics in LANL

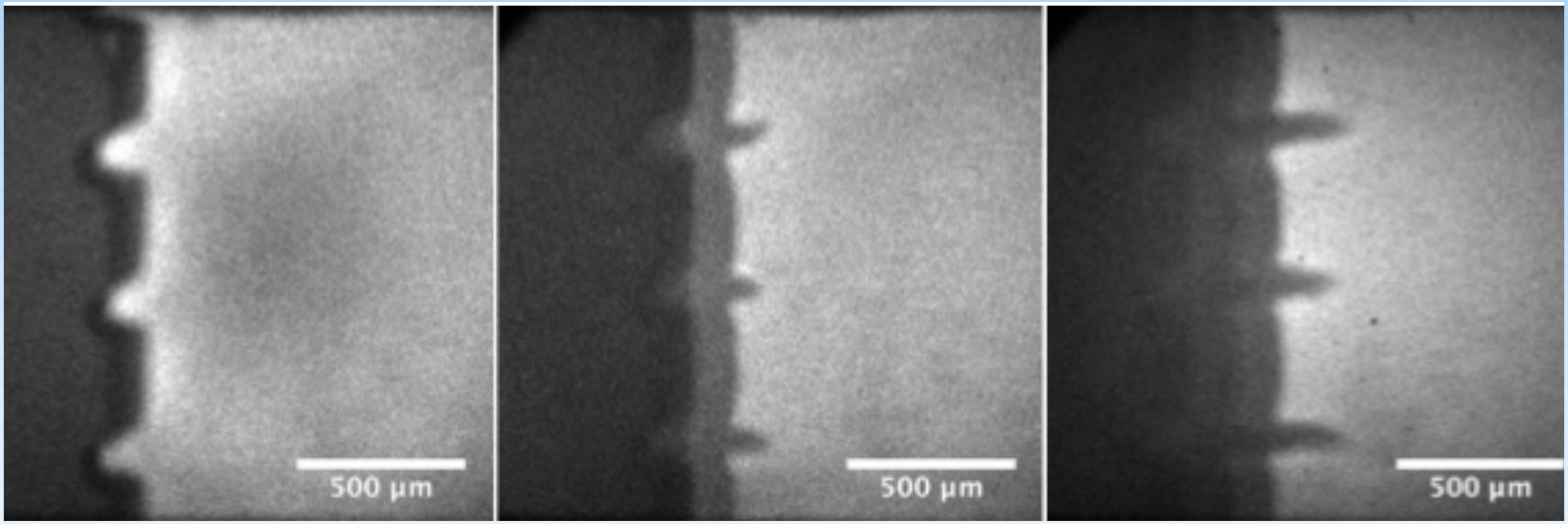
Review of work on "dusting".



IMPULSE at the Advanced Photon Source

(IMPact system for Ultrafast Synchrotron Experiments

Review of work on "dusting".



APS, IMPULSE, exposure - 80 ps, frame rate – 153 ns, area 2 x 2 mm,
Spatial resolution – 2-4 mkm

Review of work on "dusting".

Existing techniques can measure:

1. Pressure P(t), exerted on sensor by the flow
2. Velocity u(t)
3. Particle sizes (up to 2 μm)
4. Density ρ(t) - poorly
5. Mass of dust m(t) - poorly
6. They can not detect nanoparticles.

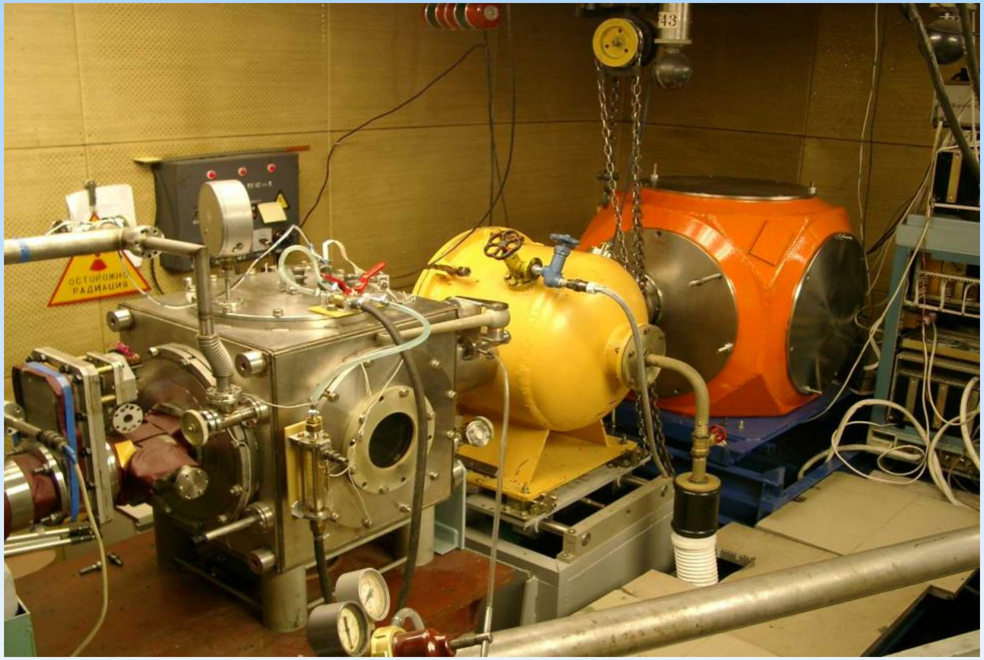
Purposes

With the help of SR registration methods carry out research of nano and micro particles flows with a free surface of various materials (copper, tin)

Obtain the dynamics of the density distribution along the flow of the microparticles formed from micron-sized gaps.

Register nanoparticles flows under shock loading different materials.

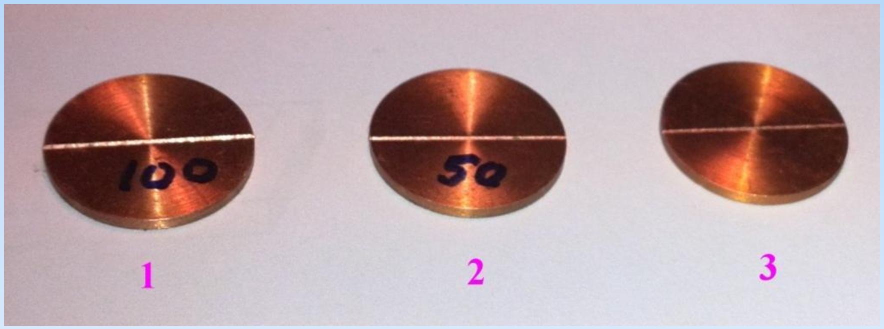
Experimental base in BINP.



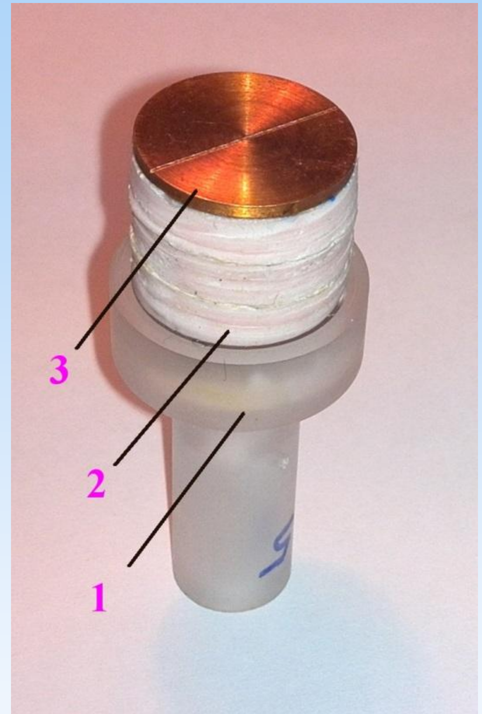
Stand for study of detonation process on VEPP-3 beam line 0.

SYRAFEEMA (Synchrotron Radiation Facility for Exploring Energetic Materials) on VEPP-4

Statement of experiments.

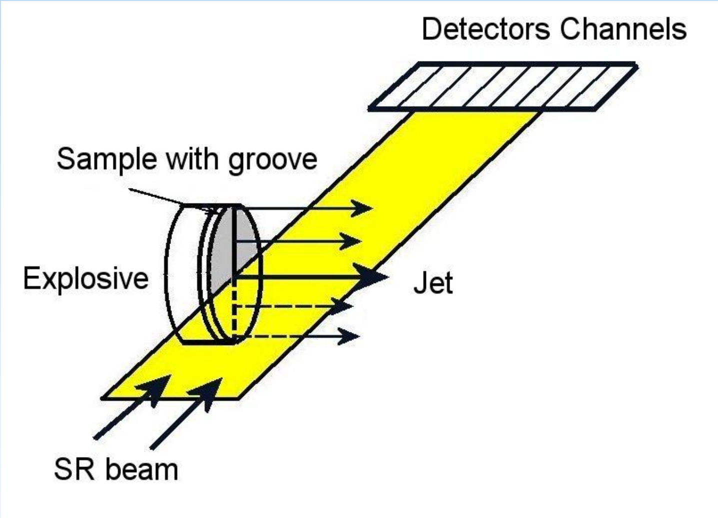


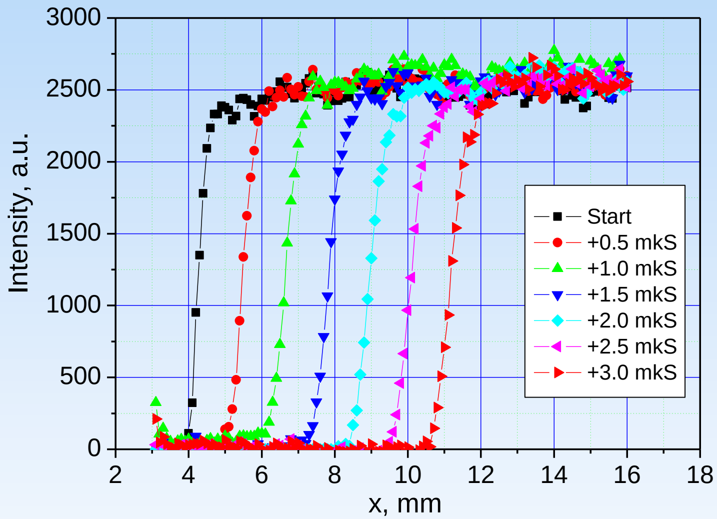
Copper disks (diameter 20 mm, thickness 2 mm) with grooves (1) - 100 microns, (2) - 50 microns, (3) - 30 microns.



The experimental assembly. 1 - explosive lenses, 2 - explosive charge, 3 - copper disc with a groove.

Statement of experiments.

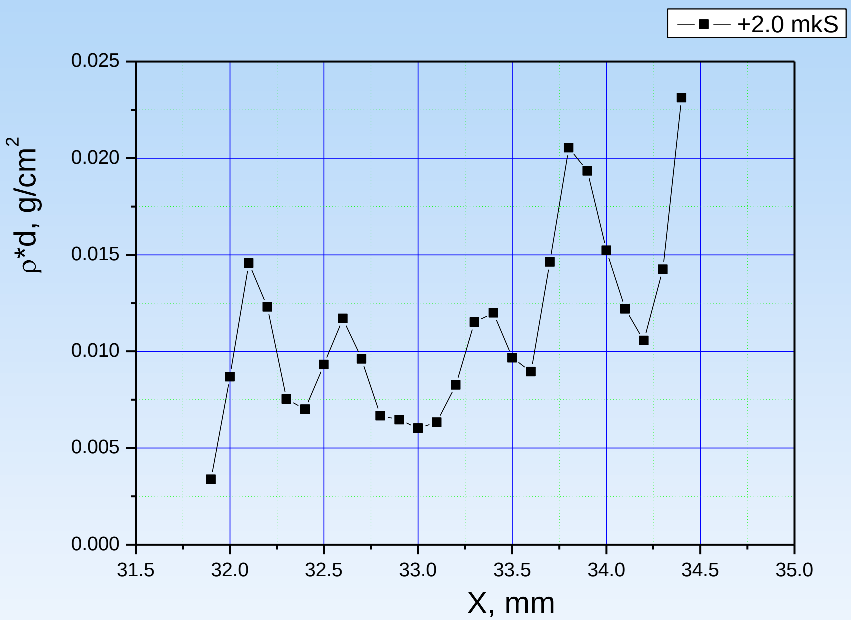


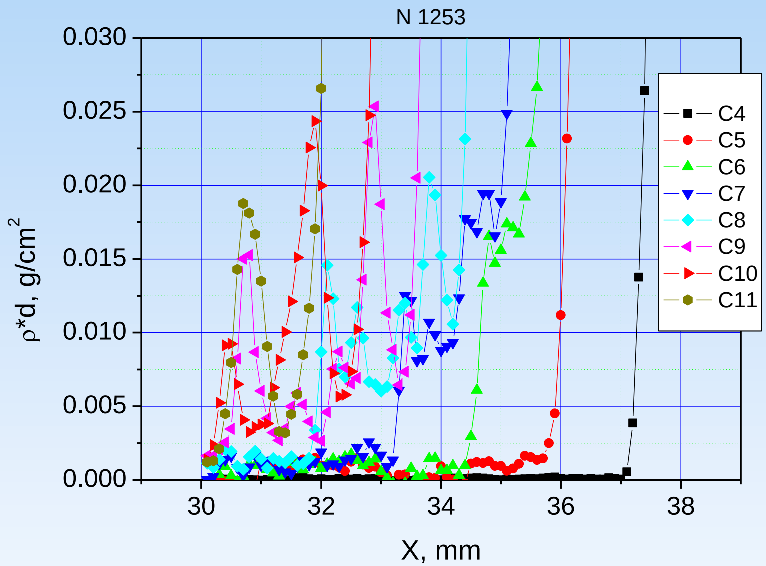


Radiographic registration in the length of microjet

Radiographic shadow of the flying disc. X is directed along the motion of the disk.

Flows of microparticles from the grooves.

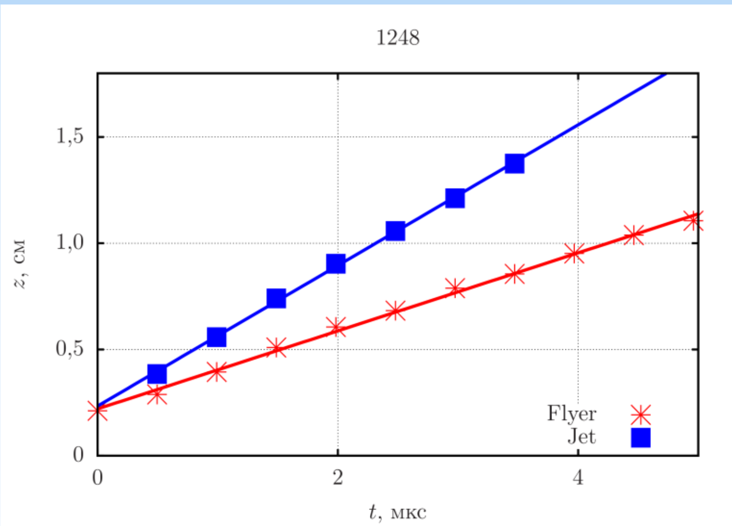




Mass distribution along the jet motion in 2 μs (right to left). Full jet mass is equal to 0.56 mg/mm (on 1 mm height).

Radiographic registration in the length of microjet (from right to left, 100 μm).

Micro-particles from the grooves.

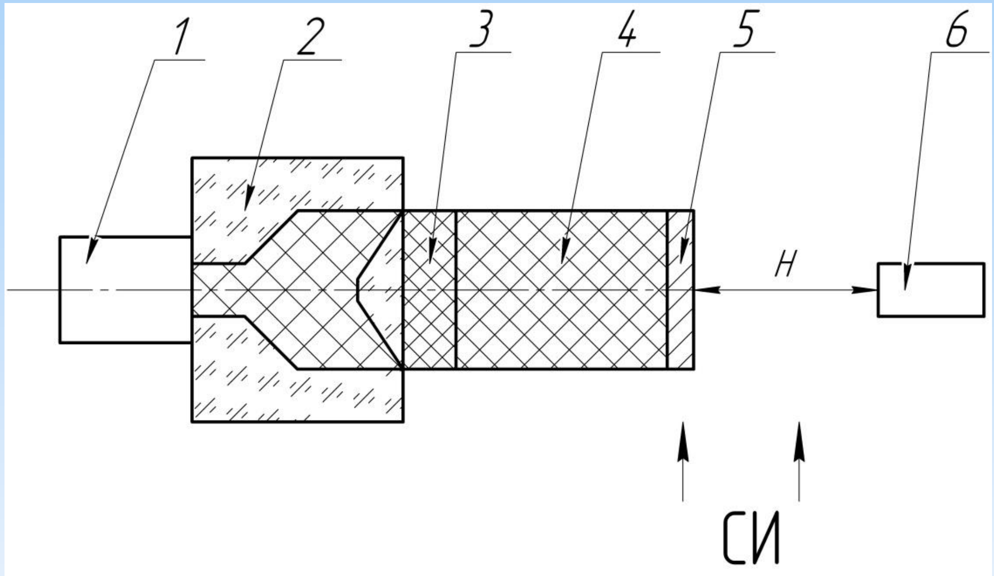


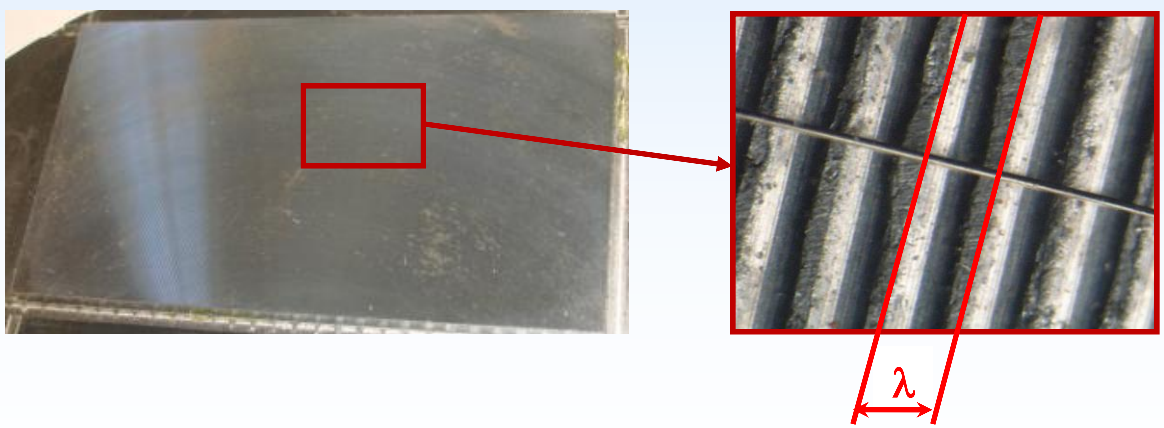
X-t diagram of jet and disc position. Velocity of the disk and the jet are 1.84 km/s и 3.31 km/s, respectively.

	Jet mass, mg		
Groove size	50 μm	100 μm	200 μм
time			
t=1 μS	0.25	0.56	0.8
t=2 μS	0.22	0.56	1.45
t=3 μS	0.14	0.5	0.97

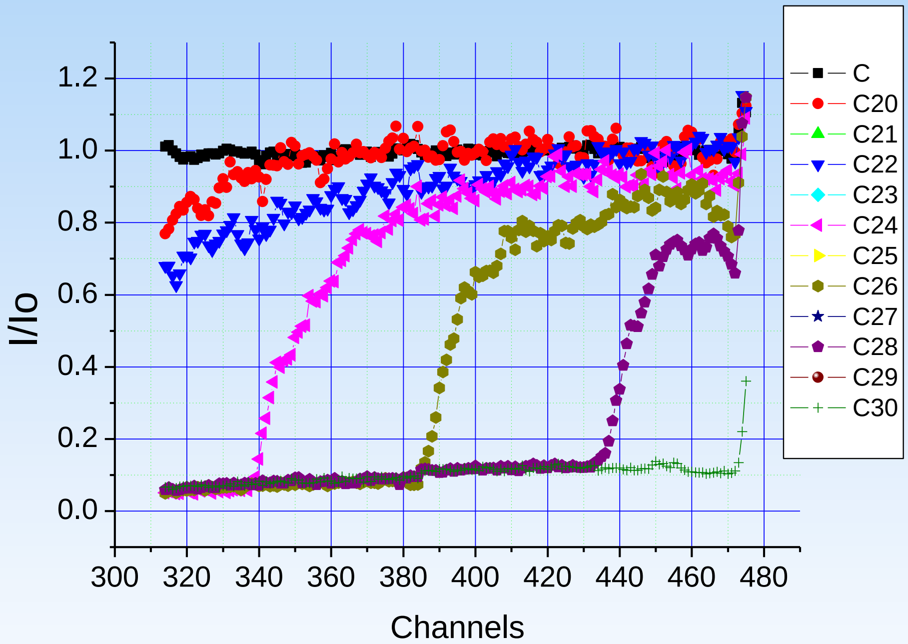
Table 1.
Dynamics the mass of the microparticles from the grooves 50, 100 and 200 microns.

Experiments with piezoelectric transducers.

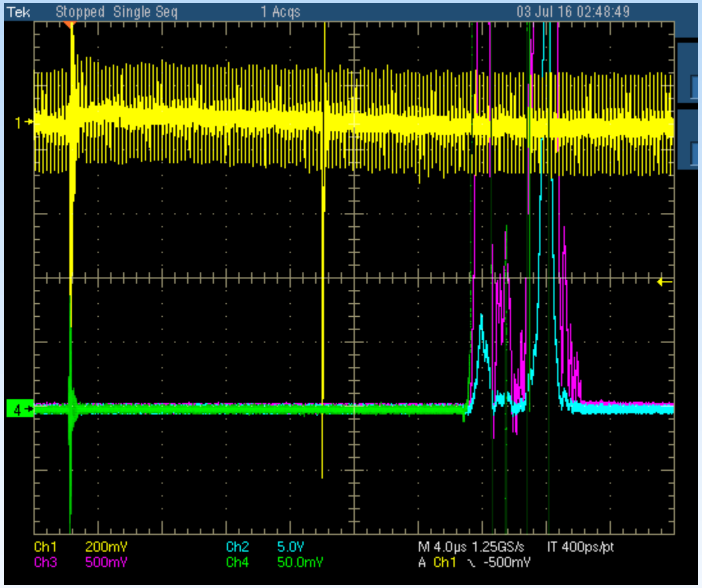




Experiments with piezo sensor.

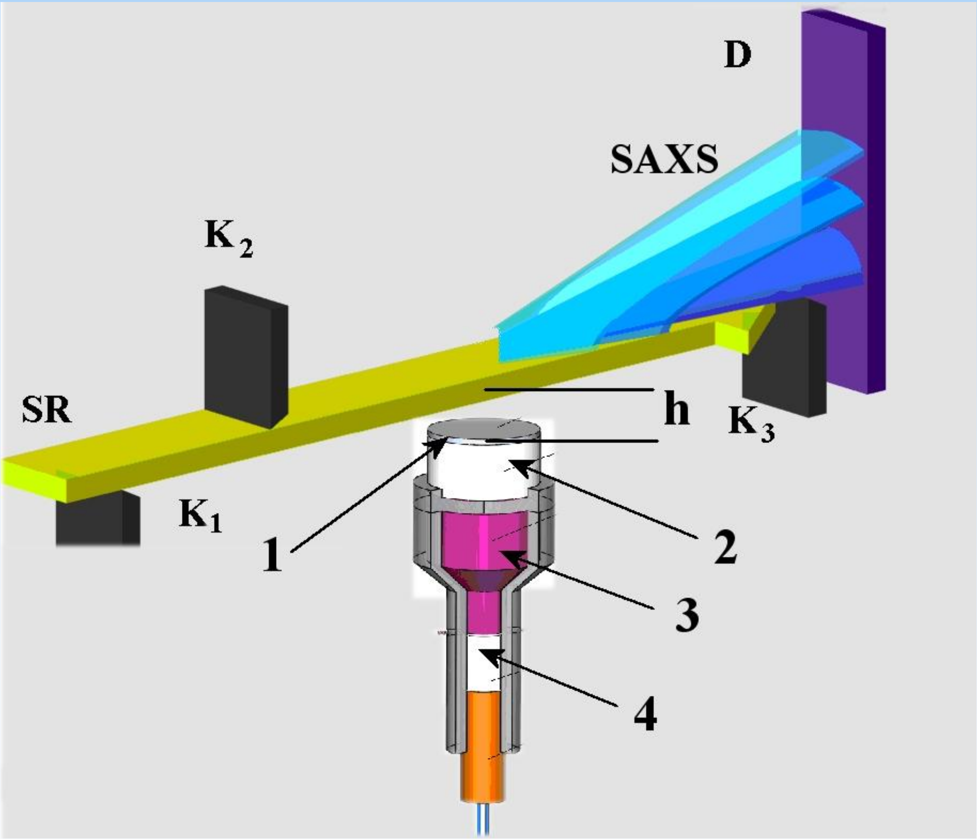


The relative intensity of SR along the flight of the particles. The time between frames is 2 μs.



Oscillogram of the piezo sensor recording.

Dynamic registration of nanoparticles. Experimental setup.

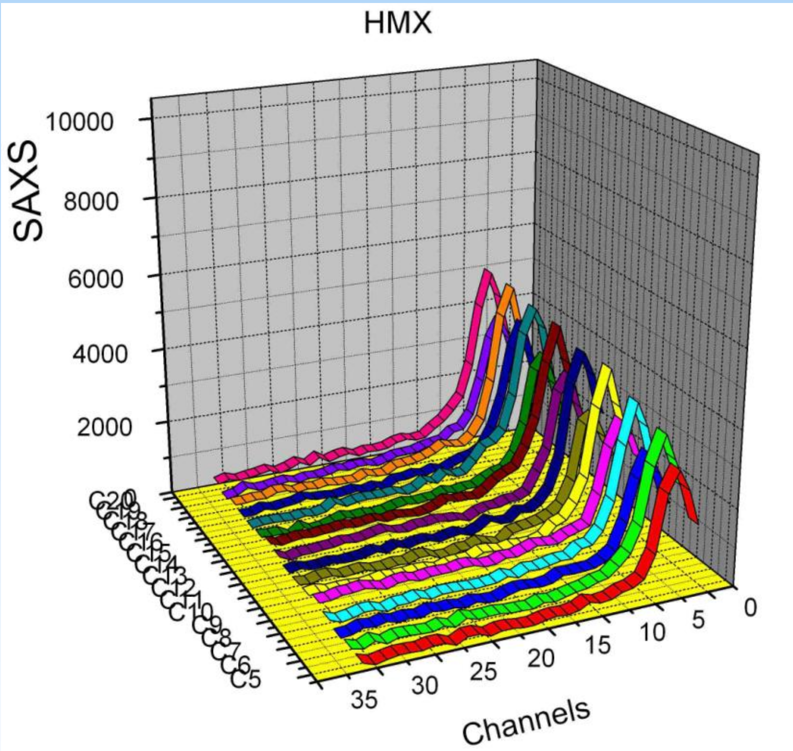


Changed in the experiments:

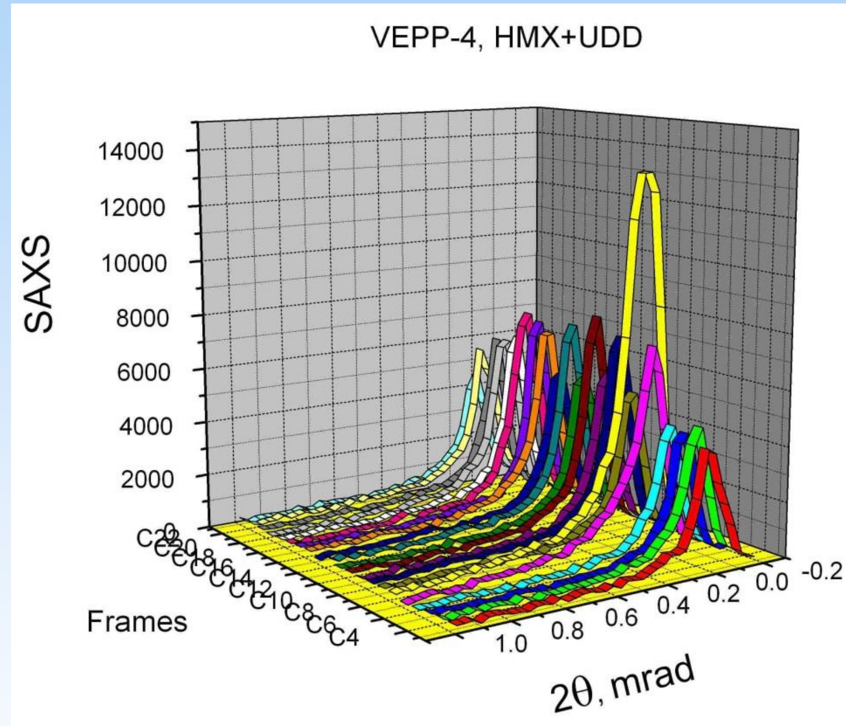
- The material of the foil (tin, UDD, tantalum, copper, molybdenum)
- Accelerating HE - pressed HMX, TG50 / 50, PT-84
- Distance between the foil and the registration plane (h)

Scheme of SAXS measuring. K1 и K2 – knife, formed incident SR beam of size of 20x0.5 mm, K3 – knife, which cut off incident beam, D – DIMEX-3 detector. h – distance between SR beam and foil. 1 – investigated foil; 2 – accelerating HE; 3 – plane wave generator; 4 – powder PETN.

Register nanoparticles during high loading of metal plates.

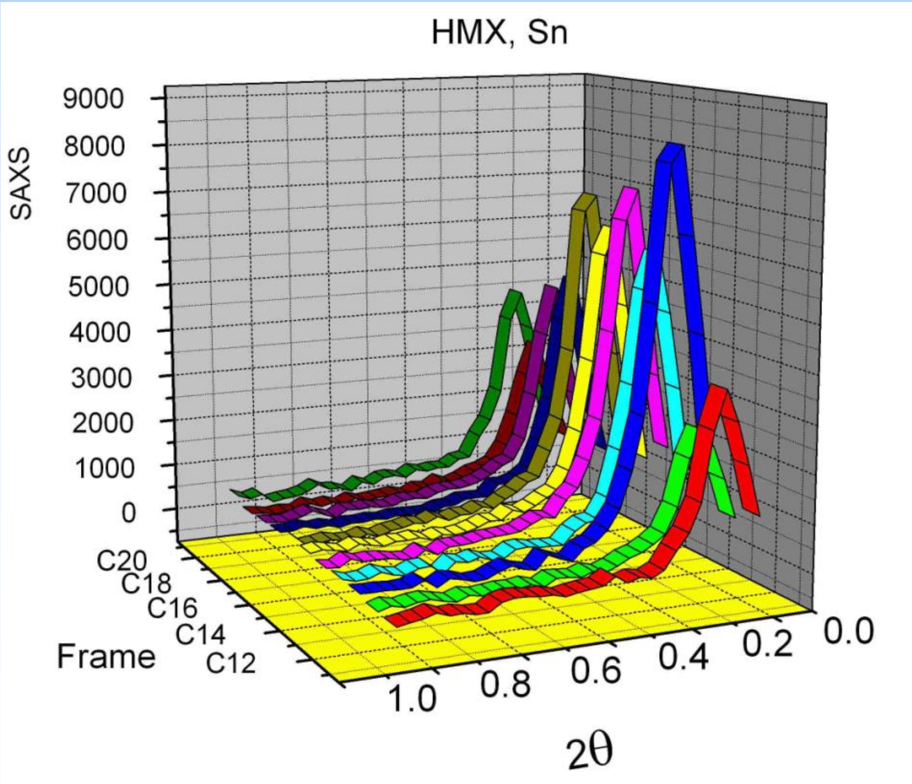


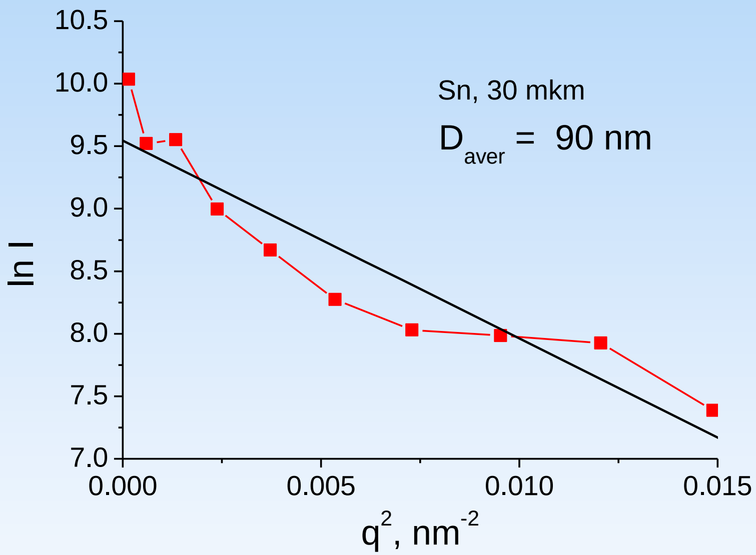
Dynamics of SAXS distributions for HMX detonation. The scattering angle 2θ is given in the detector channels. 1 channel = 0.029 mrad. Time between frames 600 ns.



Dynamics of SAXS distributions (plane is UDD). The X-axis in the scattering angle 2θ mrad. Time between frames 600 ns.

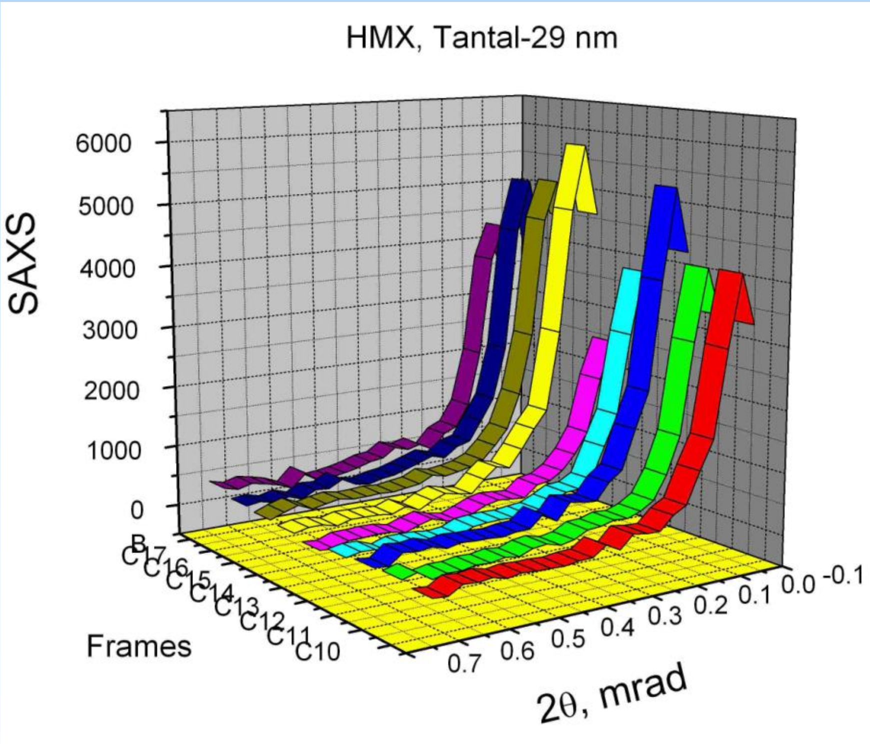
Register nanoparticles during high loading of metal plates.



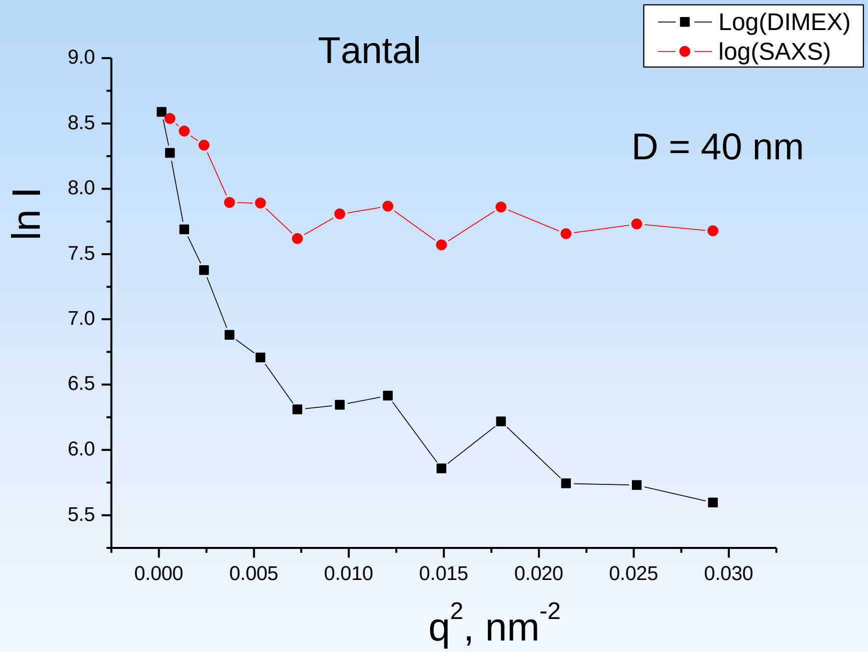


Dynamics of SAXS distributions during the moving of tin foil. The X-axis in the scattering angle 2θ mrad. Time between frames 600 ns.

Register nanoparticles during high loading of metal plates.

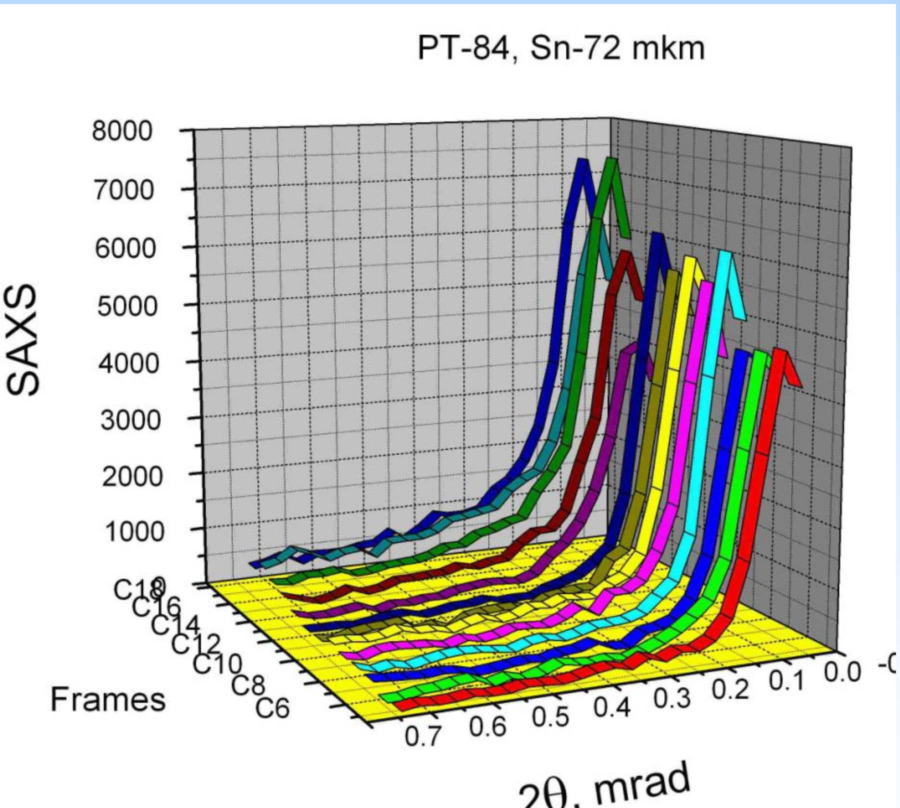


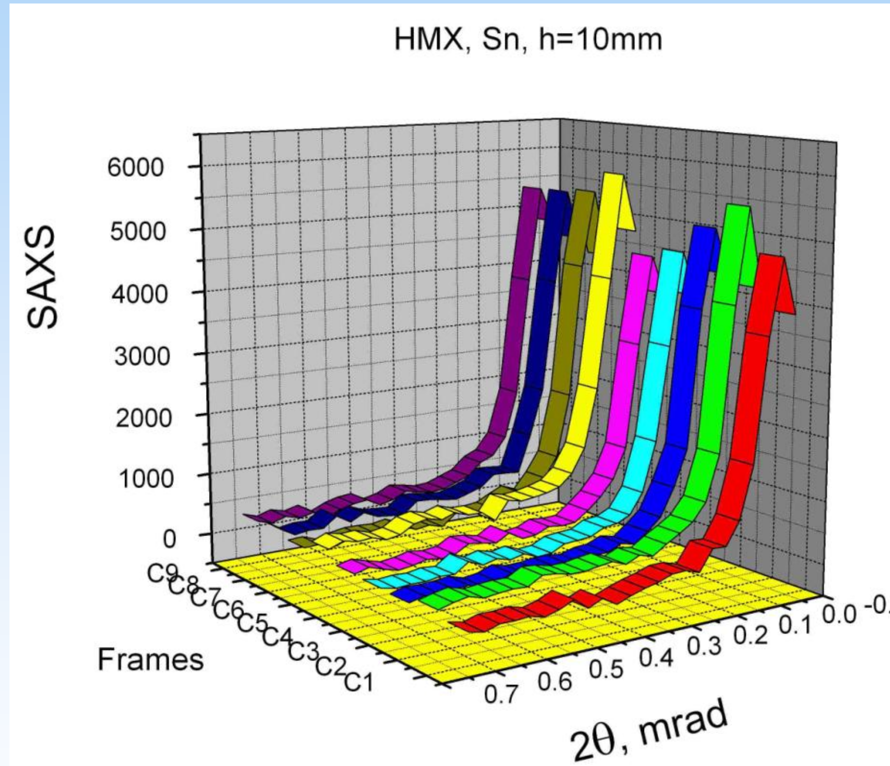
Dynamics of SAXS distributions during the moving of tantal foil. The X-axis in the scattering angle 2θ mrad. Time between frames 600 ns.



Dynamics of SAXS distributions during the moving of tin foil.
Distance to the recording plane is 10 mm Time between frames 600 ns.

Register nanoparticles during high loading of metal plates.





Dynamics of SAXS distributions during the moving of tin foil. The X-axis in the scattering angle 2θ mrad. Time between frames 600 ns.

Conclusion.

1. The dynamics of mass distribution along the flow of the microparticles from micro grooves was measured.
2. Simultaneous recording of SR and signal from piezoelectric transducers were made.
3. When throwing a foil (with a thickness from 20 to 70 nm) in front of a tin was recorded stream of nanoparticles (of about 100 nm).
4. Of the investigated materials (Cu, Mo, Al, Ta) flow nanoparticles was registered of tantalum (about 40 nm in size).

Thank you for your attention

http://ancient.hydro.nsc.ru/srexpl

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