The velocity measurement of shocks generated by x-ray radiation in different materials at "Iskra-5" laser

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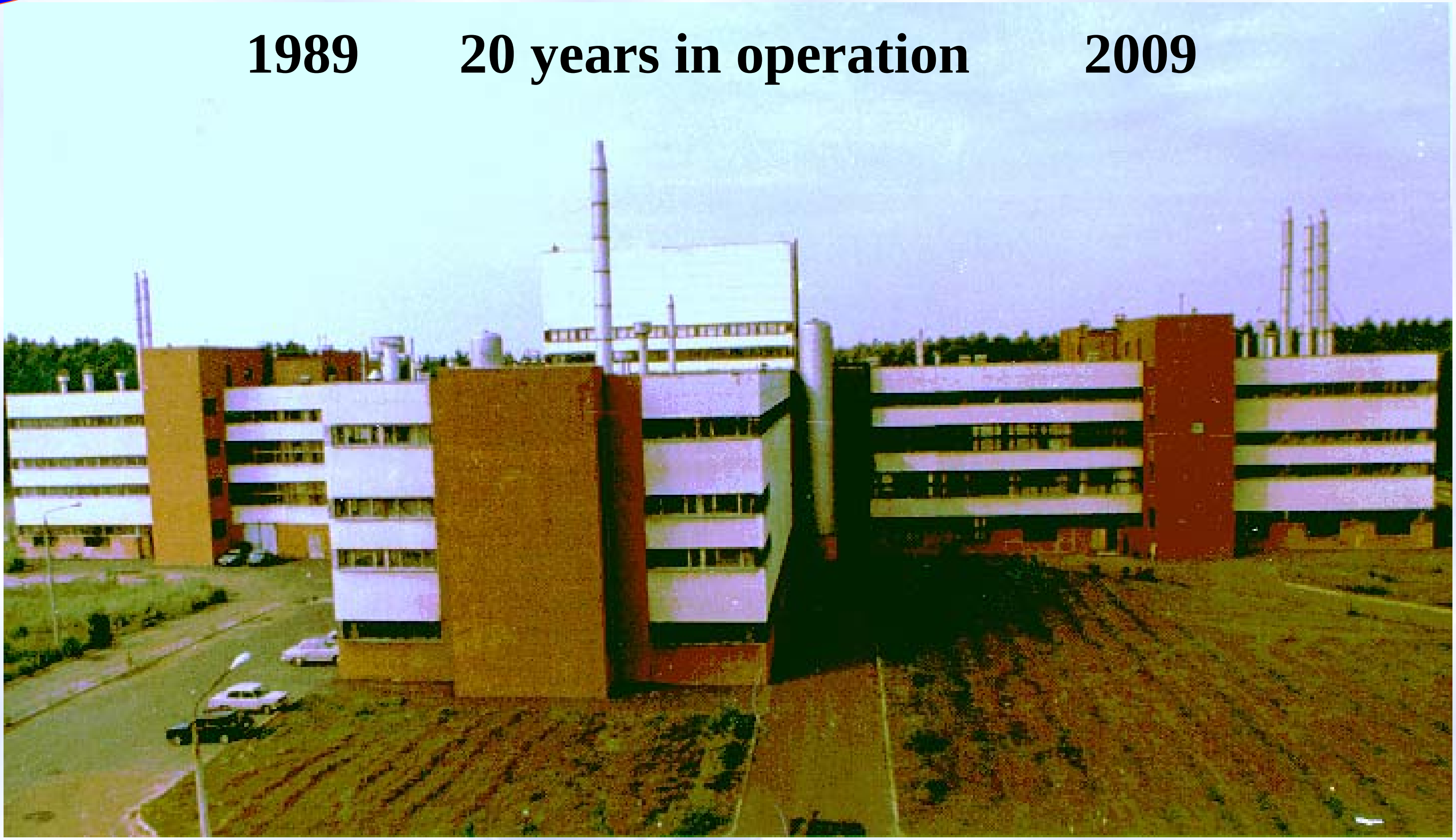
Presented by N. Zhidkov

RFNC-VNIIEF "ISKRA-5" laser facility

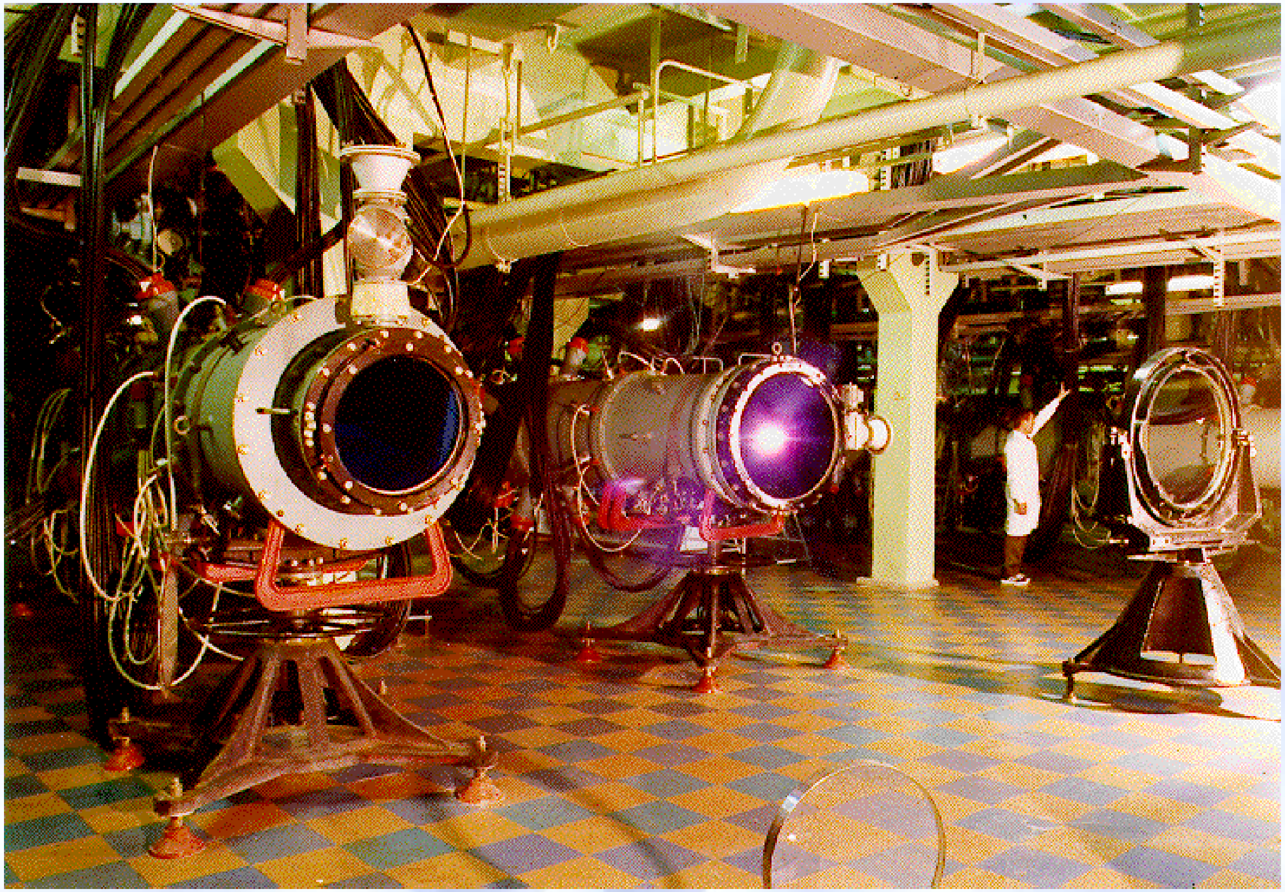
1989 20 years in operation 2009



12 channels. Wavelength 1.315 μm. First harmonic energy up to 30 kJ. Pulse duration 0.4 ns. Power ~ 100 TW.

RFNC-VNIIEF "ISKRA-5" laser facility

One of the Optical Halls



The whole length of one channel is 250 m. Beam diameter - 700 mm. Wavelength 1.3 μm. Pulse duration 0.4 ns.

Laser energy up to – 1.2kJ/channel. Beam divergence - 6 10^{-5} rad.

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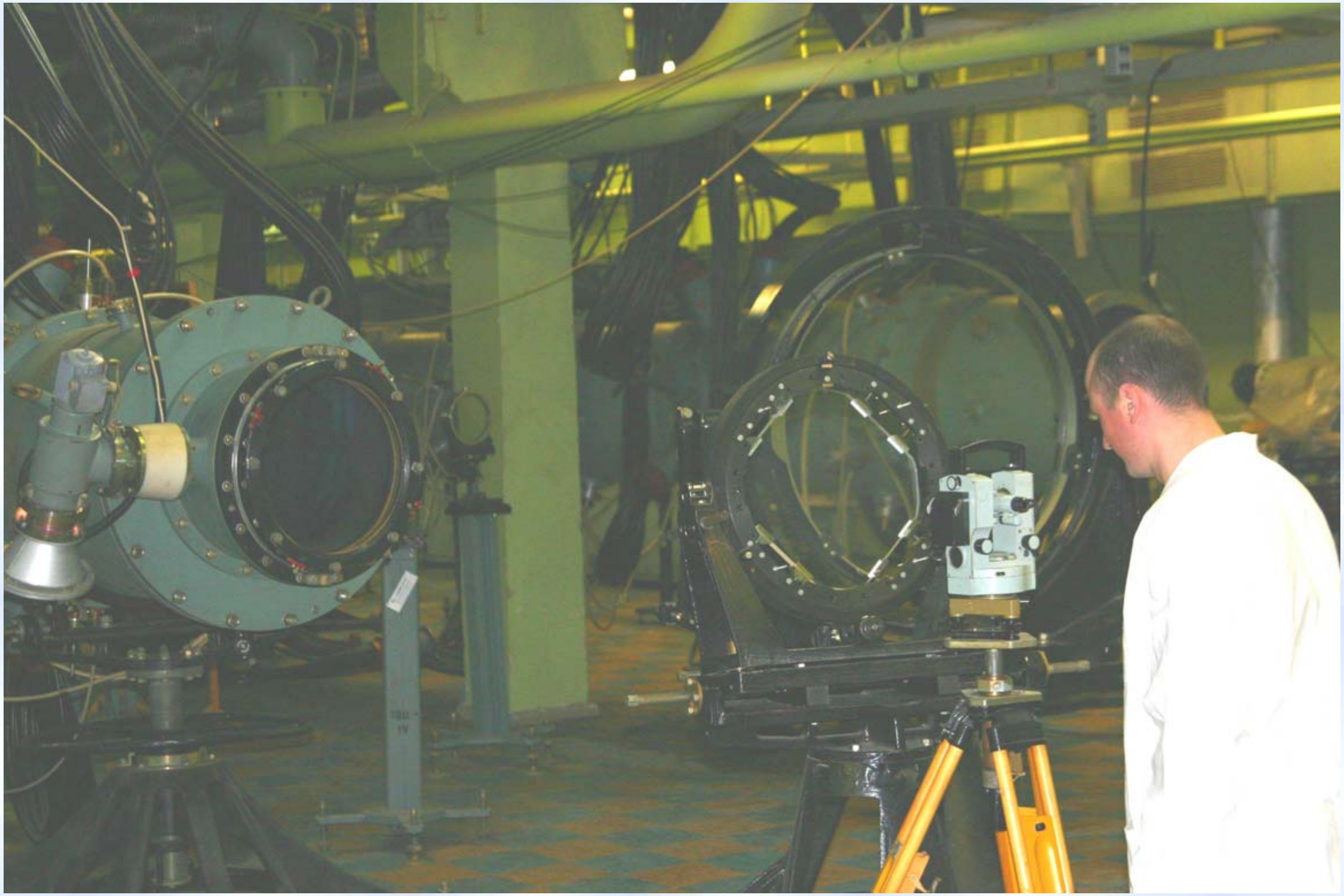
Since 2003 - second harmonic /DKDP crystal with 32 x32 cm aperture/



Wavelength 0.66 μm. Second harmonic energy up to 400J/channel. Pulse duration 0.4 ns.

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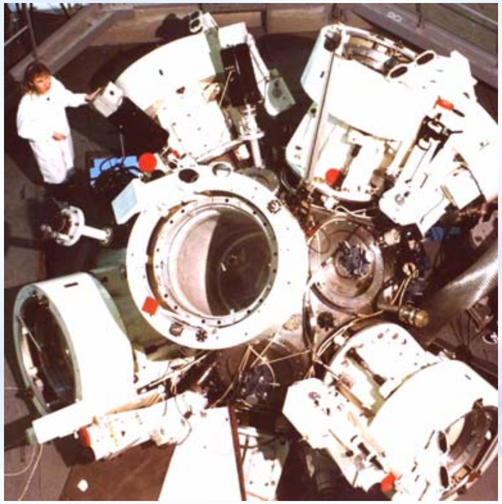
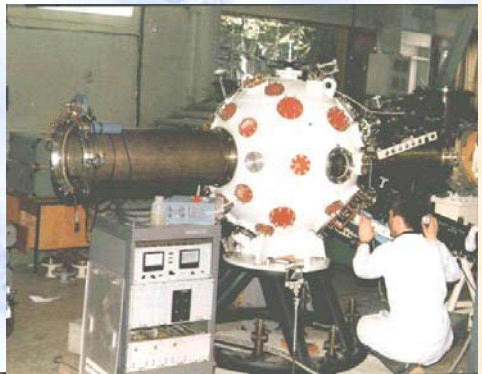
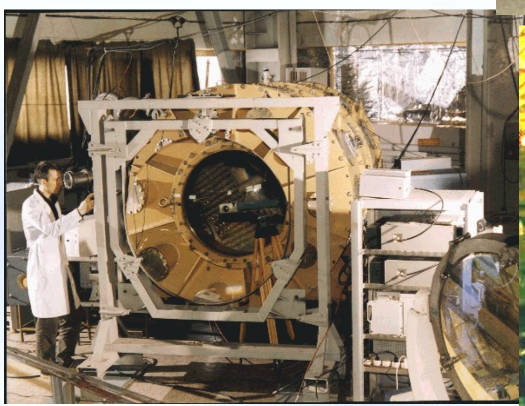
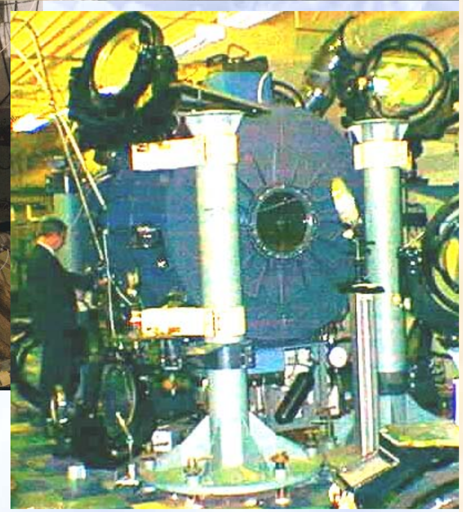
Target chambers and diagnostics









Diagnostic methods

1. Energy balance - array of light and plasma calorimeters.
2. Control of laser pulse contrast and plasma expansion – interferogram (or shadowgraph) of the target by probe laser beams.
3. Plasma ions:
   - Array of Faraday caps.
   - Tompson mass-spectrometer.
4. X-ray image - array of pinhole cameras.
5. X-ray spectrum:
   - Dante X-ray spectrometer (0.1-1.5 keV).
   - Array of X-ray and P-i-N diodes (1.5-100 keV).
   - X-ray streak cameras.
   - X-ray frame camera.
6. Set of X-ray spectrographs:
   - Transmission grating.
   - Grazing diffraction grating.
   - Flat crystals.
   - Cylindrical and elliptical crystals.
   - Spherical crystals.
7. Neutron yield - Cu and In activation.
8. Fuel temperature - neutron time of flight measurement.

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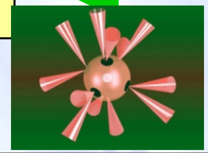
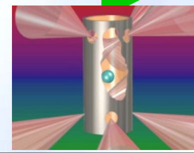
Inverted corona target (CD_2 layer)

Spherical hohlraum



Cylindrical hohlraum



High temperature non-equilibrium plasma

Capsule compression in high symmetric X-ray flux (asymmetry less than 3%)

Capsule compression in asymmetric X-ray flux (controllable asymmetry)

ILLUMINATOR X-ray source T_{max}~150 - 170 eV

EXPERIMENTAL RESEARCHES

X-ray transport and material heating

Turbulent mixing

EOS

Opacity

Kinetic processes, X-ray spectrum (various materials)

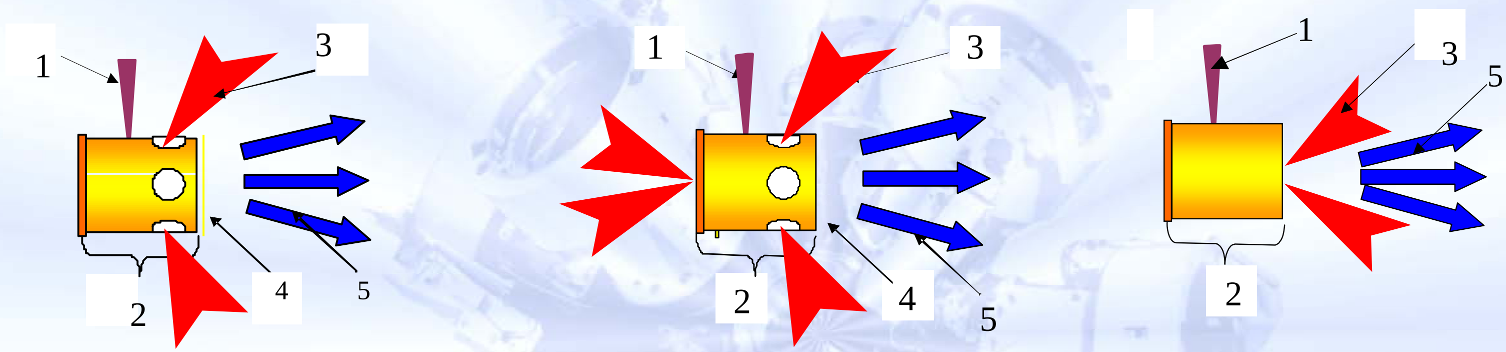
Compression of asymmetric capsule in high symmetric X-ray flux

Methods of asymmetry compensation

Flat targets (diagnostics improvement and calibration)

X-ray laser

Experimental research of X-ray source “Illuminator” at the “Iskra-5” second harmonic operation



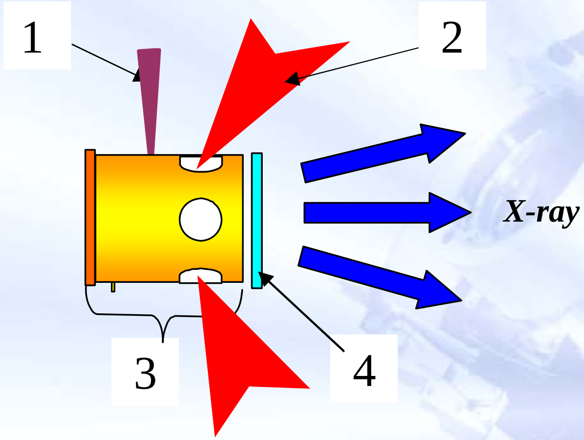
Four beams **Six beams** **Two beams**

Three types of “Illuminator” scheme

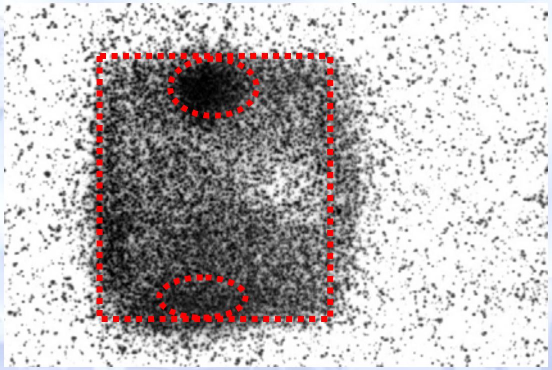
1 - holder, 2 –case(∅0.6x0.6 mm), 3 – laser beams, 4 – output window, 5 –X ray flux

RFNC-VNIIEF "ISKRA-5" laser facility

Images of Illuminator in hard X-ray

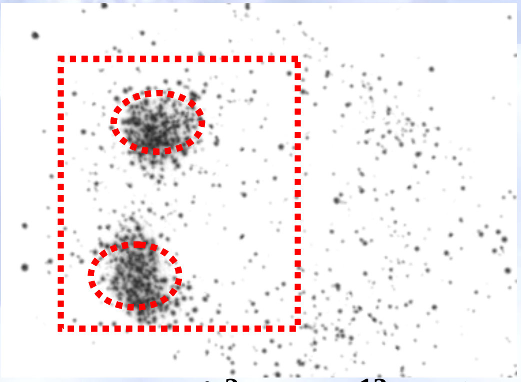


Illuminator
1 - holder, 2 – laser beams, 3 – case, 4 - filter



$I\lambda^2 \approx 9\ 10^{13}$ W/(cm² μm²)

1ω hν > 60 keV
E ≈ 1.3 kJ τ ≈ 0.4 ns



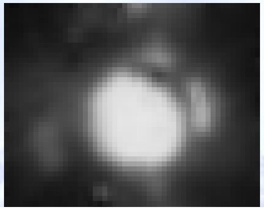
$I\lambda^2 \approx 2\ 10^{13}$ W/(cm² μm²)

2ω hν > 10 keV
E ≈ 0.8 kJ τ ≈ 0.4 ns

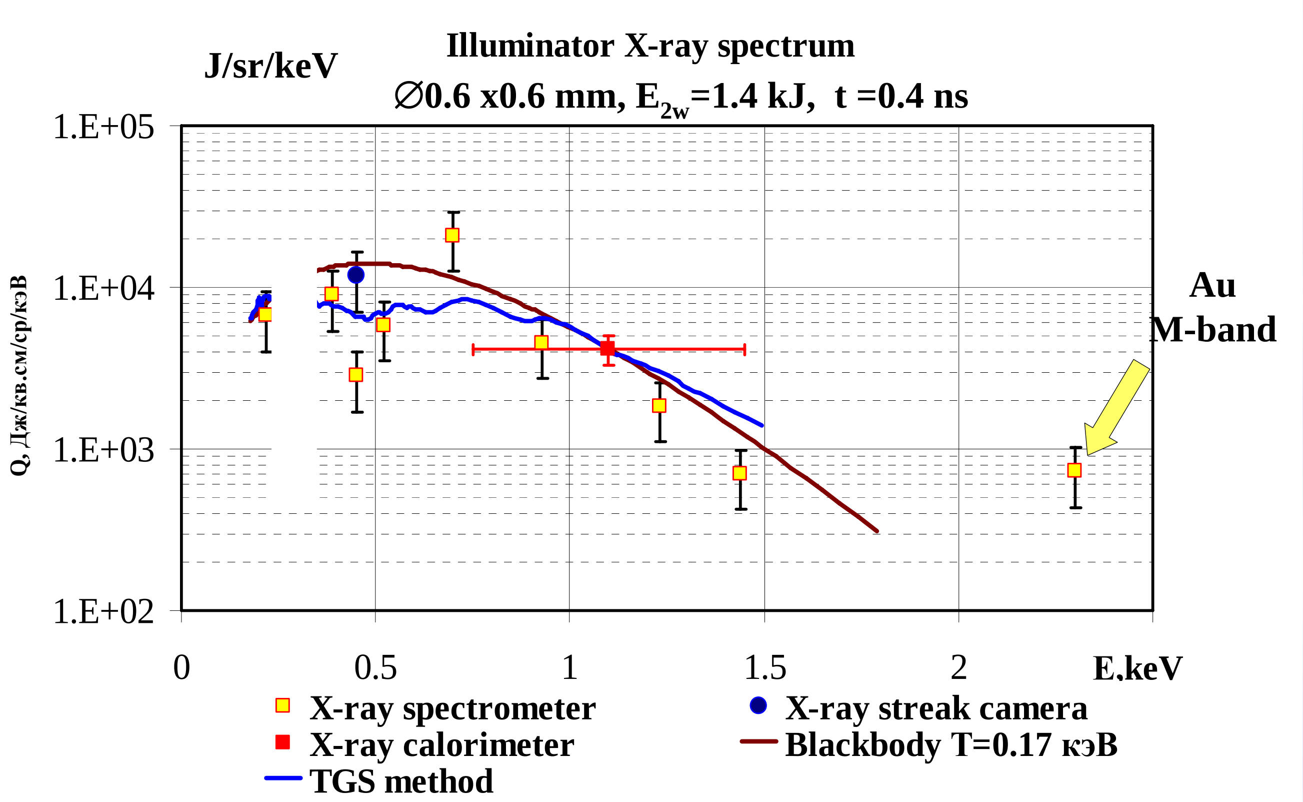
Illuminator contour boundary – red dotted line

RFNC-VNIIEF “ISKRA-5” laser facility

Experimental research of X-ray source “Illuminator” at the “Iskra-5” second harmonic operation



X-ray image



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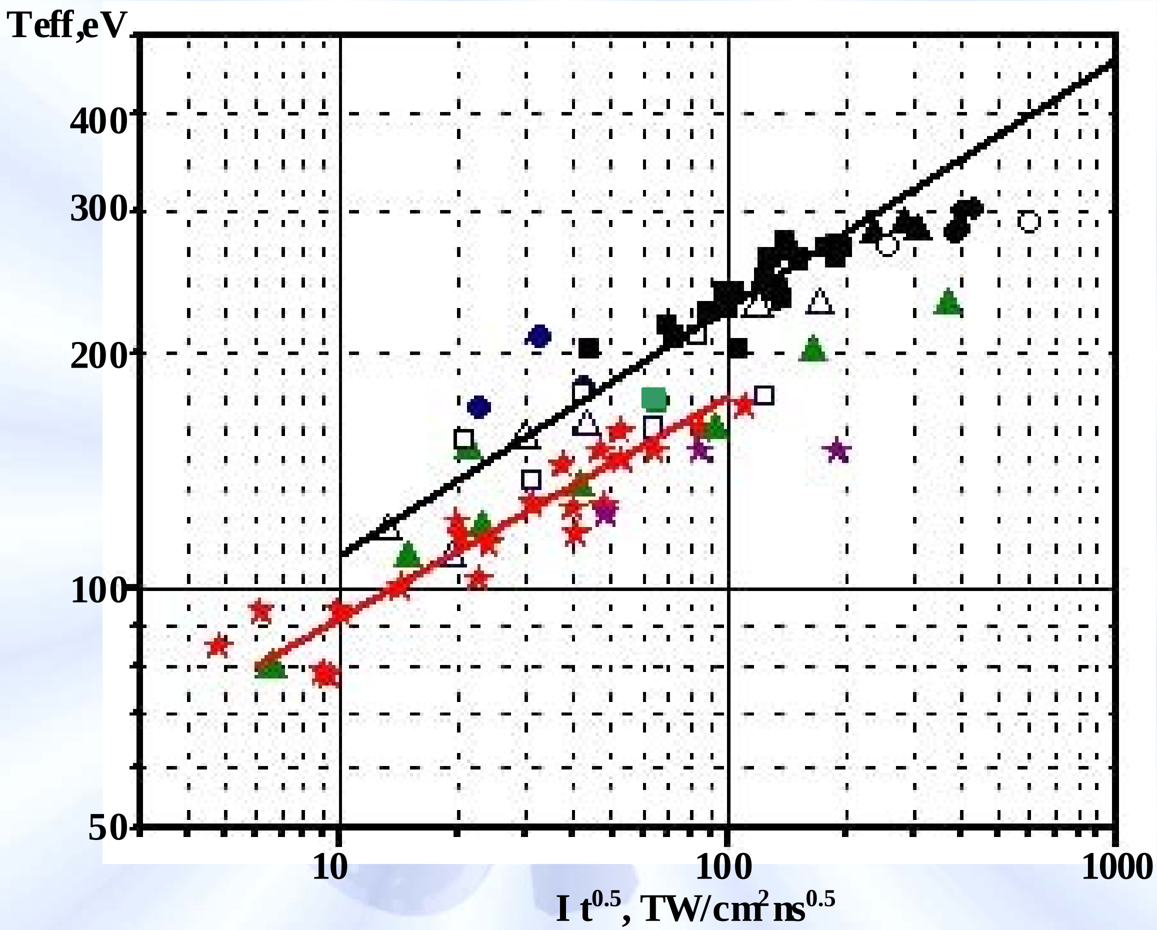
Comparison of experiments with box-converters at various facilities



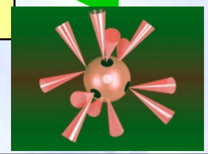
■ ▲ ⬢ ⬡ Nova, □ Phebus, △ GekkoXII, ▬ Scaling, 0.35 мкм
■ Novetta, 0.53 mkm [J.Lindl, Phys. Plasmas, 2, 3933 (1995)]

▲ Helen(UK), 0.53 mkm [R.M.Stevenson, et.al., Phys.Rev.Lett, 94, 055006 (2005)]
★ Iskra5, 1.3 mkm ★ Iskra5, 0.66 mkm

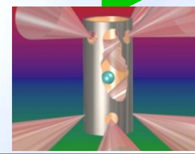
RFNC-VNIIEF "ISKRA-5" laser facility

Inverted corona target (CD_2 layer)

Spherical hohlraum



Cylindrical hohlraum



High temperature non-equilibrium plasma

Capsule compression in high symmetric X-ray flux (asymmetry less than 3%)

Capsule compression in asymmetric X-ray flux (controllable asymmetry)

ILLUMINATOR X-ray source T~150 eV

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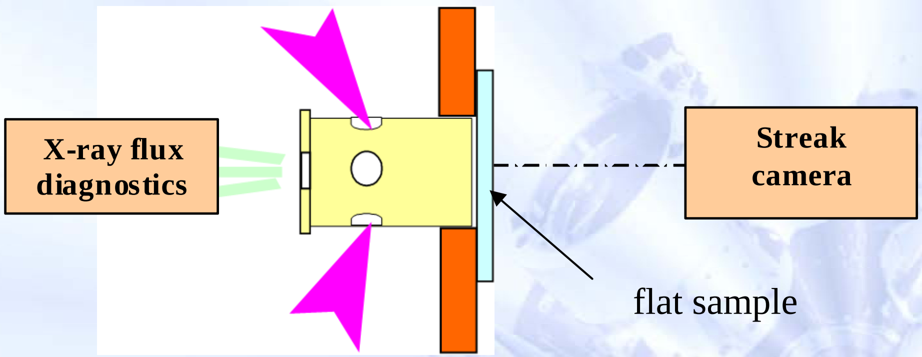
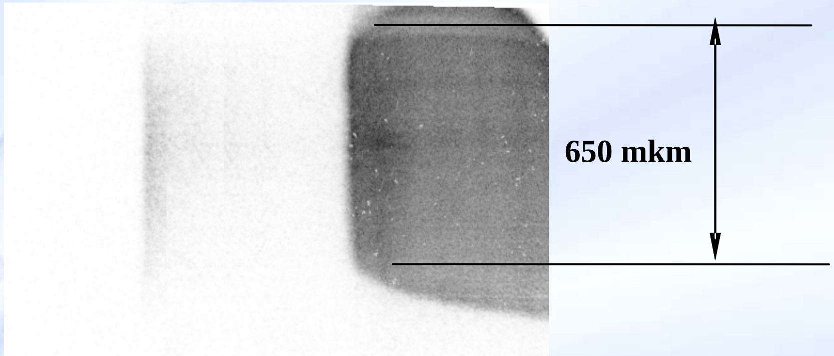
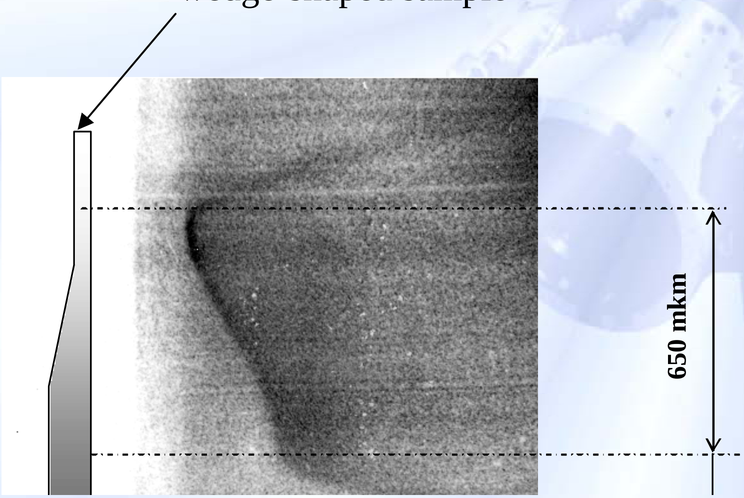
X-ray laser

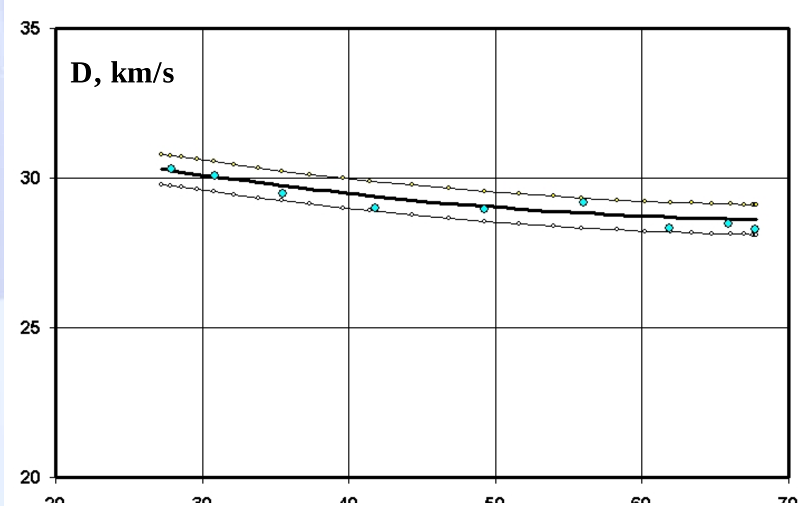
Investigation of shock velocity uniformity and stationarity





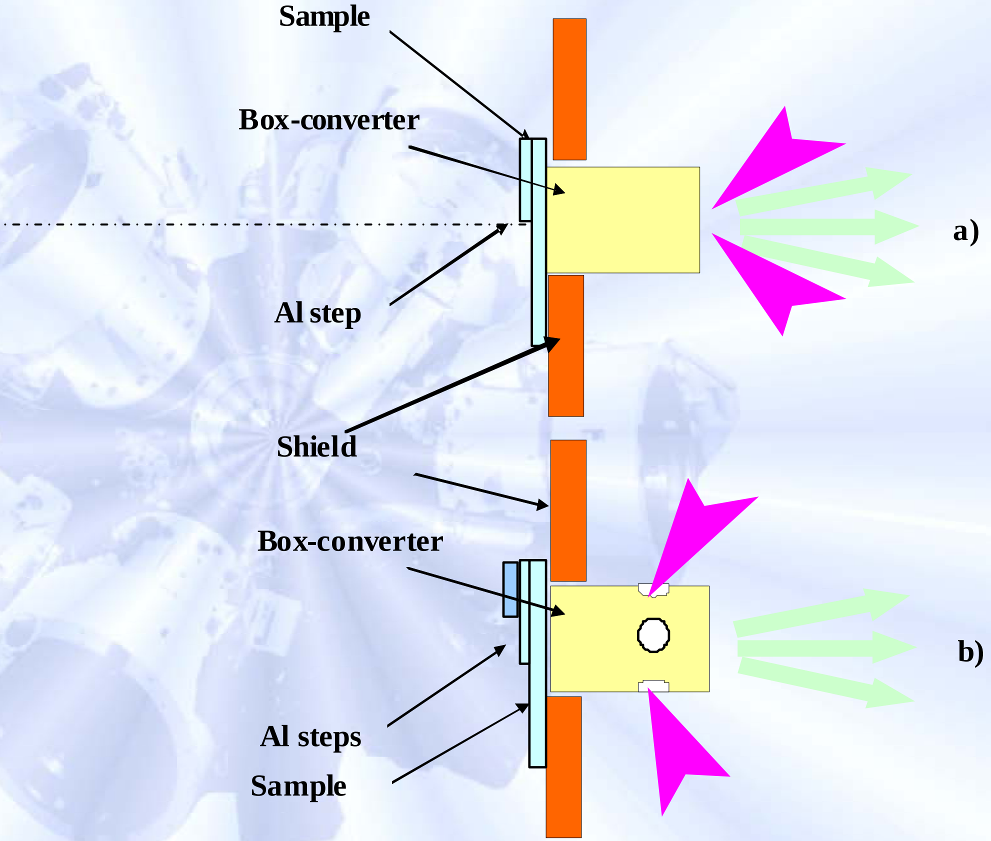
The time diversity on diameter correspond to nonuniformity of shock velocity less then 3%.

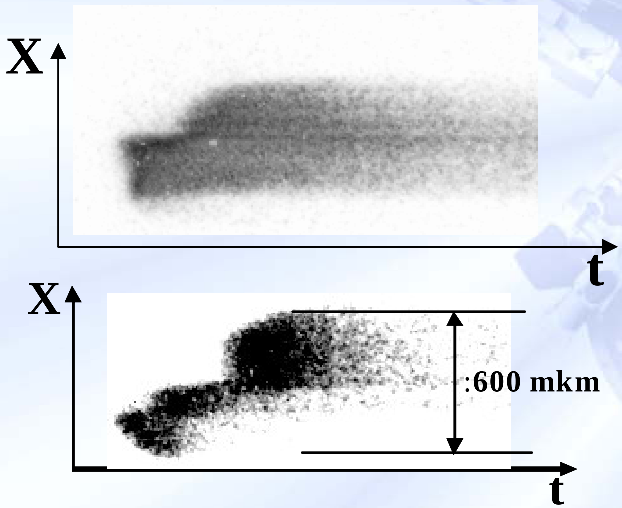




nonstationarity of shock velocity less then 5%

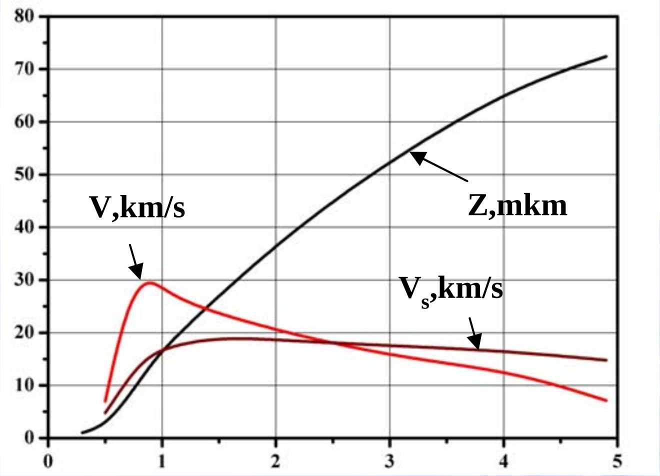
Registration of the shock wave velocity in Al samples for X-ray temperature measurements

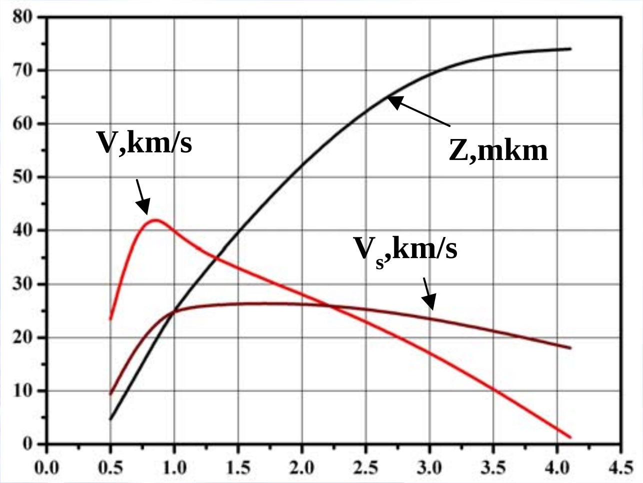




Examples of streak camera registration

Temporal behavior of the shock generated by X-ray in Al
Calculation results





a) $T_R \approx 120$ eV

b) $T_R \approx 140$ eV

$T_R[eV] \approx 22.1\ V_s^{0.58}$ [km/s] - VNIIEF

$T_R[eV] \approx 17.6\ V_s^{0.63}$[km/s] - LLNL

Approximations

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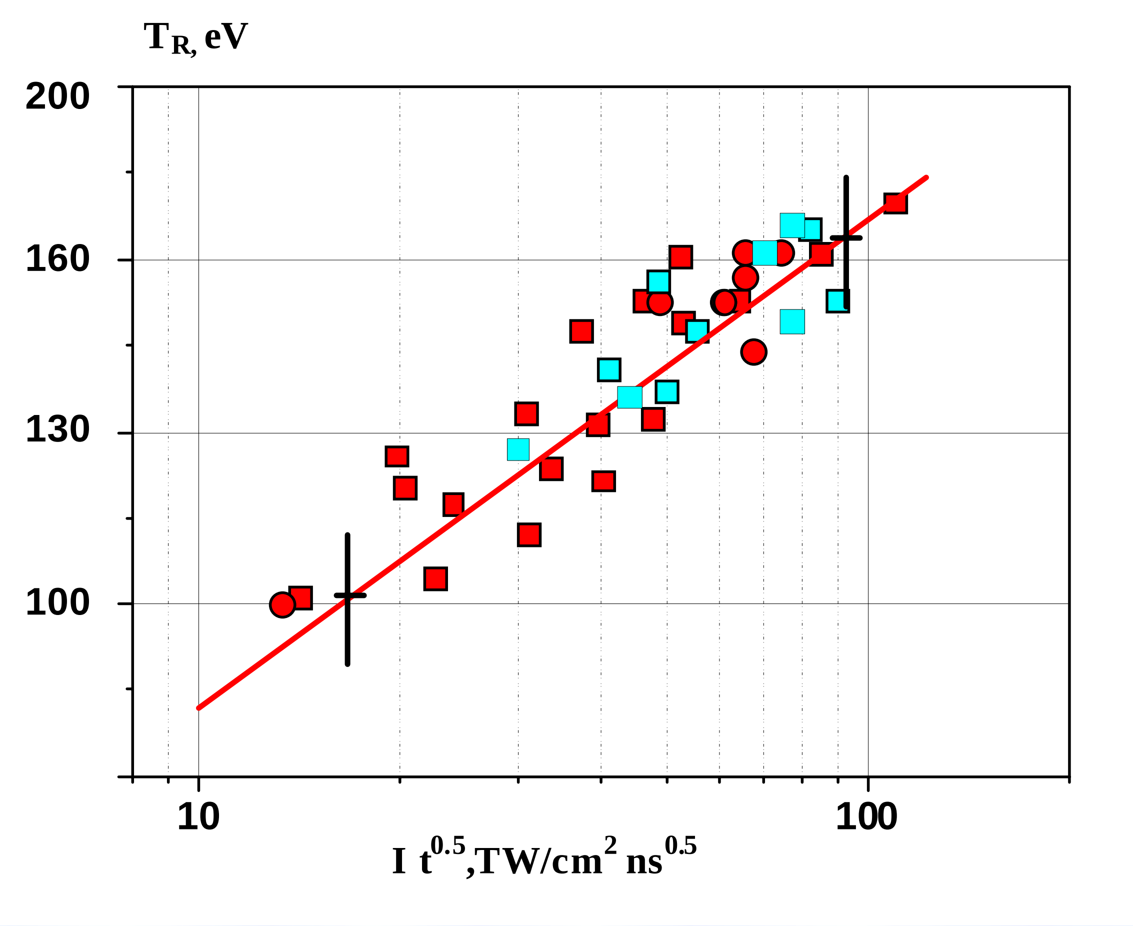
Results of the X-ray temperature measurements



(■) Cylindrical boxes (●) Spherical boxes – X-ray flux measurements

(■) –Measurements of the shock wave velocity in Al

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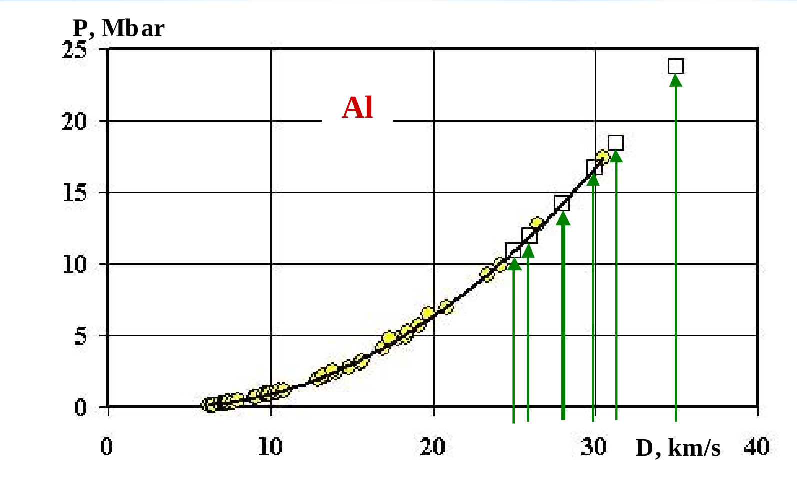
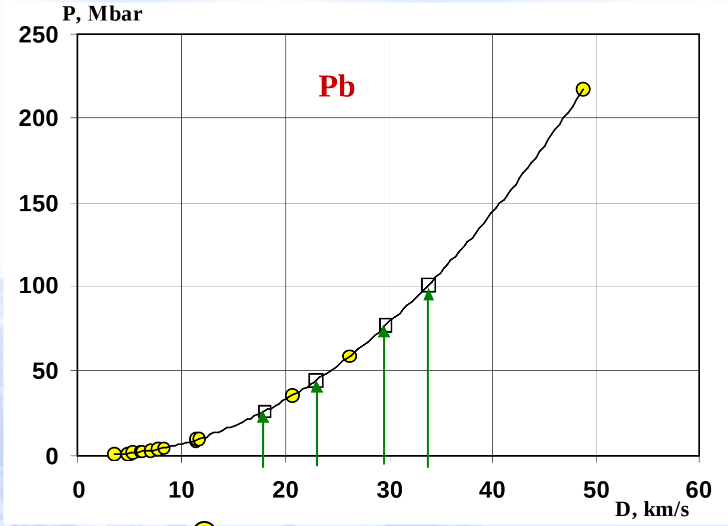
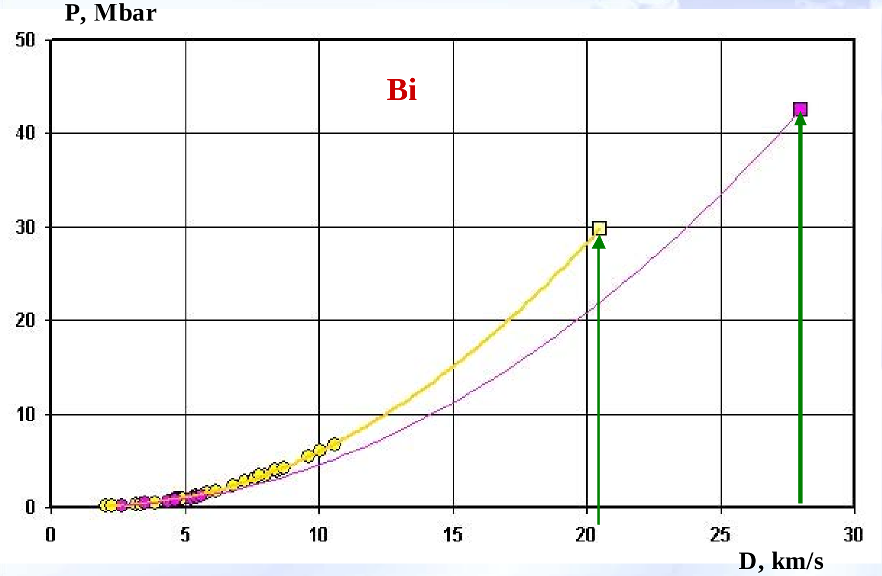
The shock velocity measurement in different materials



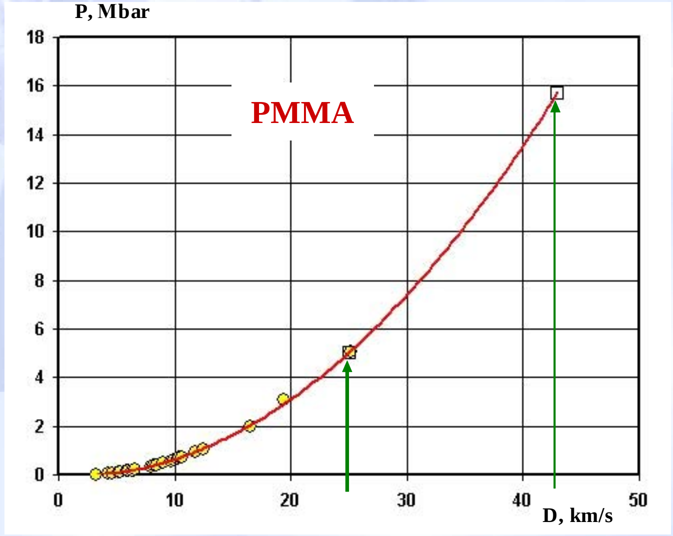
Data *) Iskra-5



Data*) Iskra-5



(ρ=9.9 г/см³), (ρ=6.6 г/см³) Data*)
(ρ=10.2 г/см³), (ρ=6.3 г/см³) Iskra-5



Data*) Iskra-5

*) R.F. Trunin. Data on shock compression and adiabatic expansion of condensed materials. Sarov. 2006

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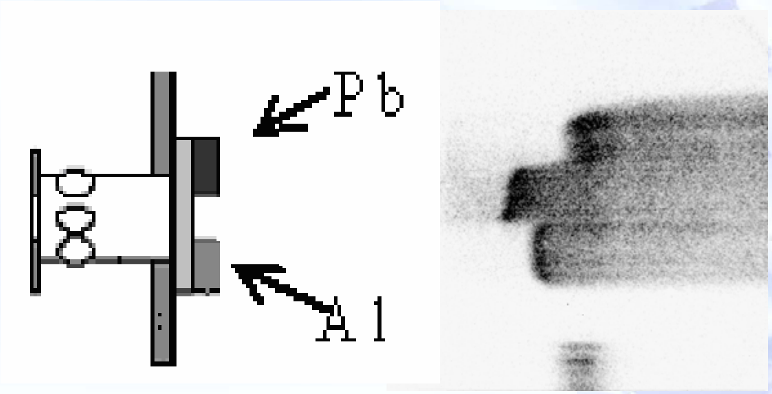
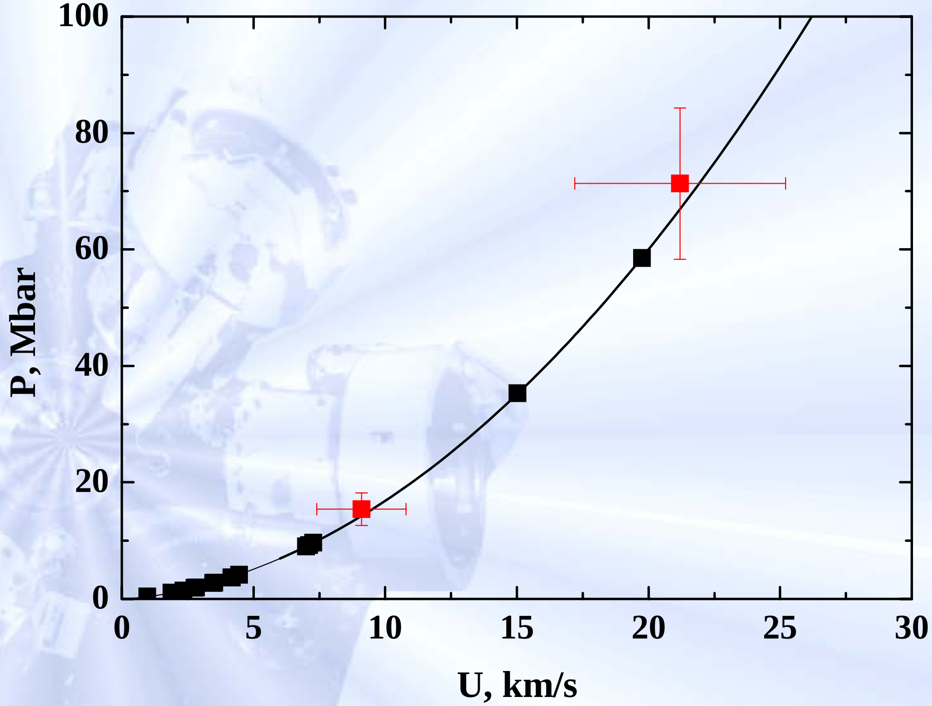
Impedance-match method



Example of streak camera registration

PU-diagram of Pb



■ - Data *) (VNIIEF); ■ - ISKRA-5 results.

*) R.F. Trunin. Data on shock compression and adiabatic expansion of condensed materials. Sarov. 2006

Conclusion

The method on the of shock velocity registration in various materials has been developed at "Iskra-5" facility in the indirect-drive targets experiments.
The X-ray temperature on the Al target surface has been measured in the experiments with indirect –drive targets by shock velocity registration.
The experimental results coincide within the error bar with results of the methods which use the measurement of absolute X-ray fluxes.

The obtained shock velocities for Al, Pb, Bi and PMMA are significantly higher than the velocities in the ordinary shock tubes.

Authors acknowledge all colleagues from "Iskra-5" facility for the help in experiments conducting.