Uniform irradiation of targets on powerful laser facilities

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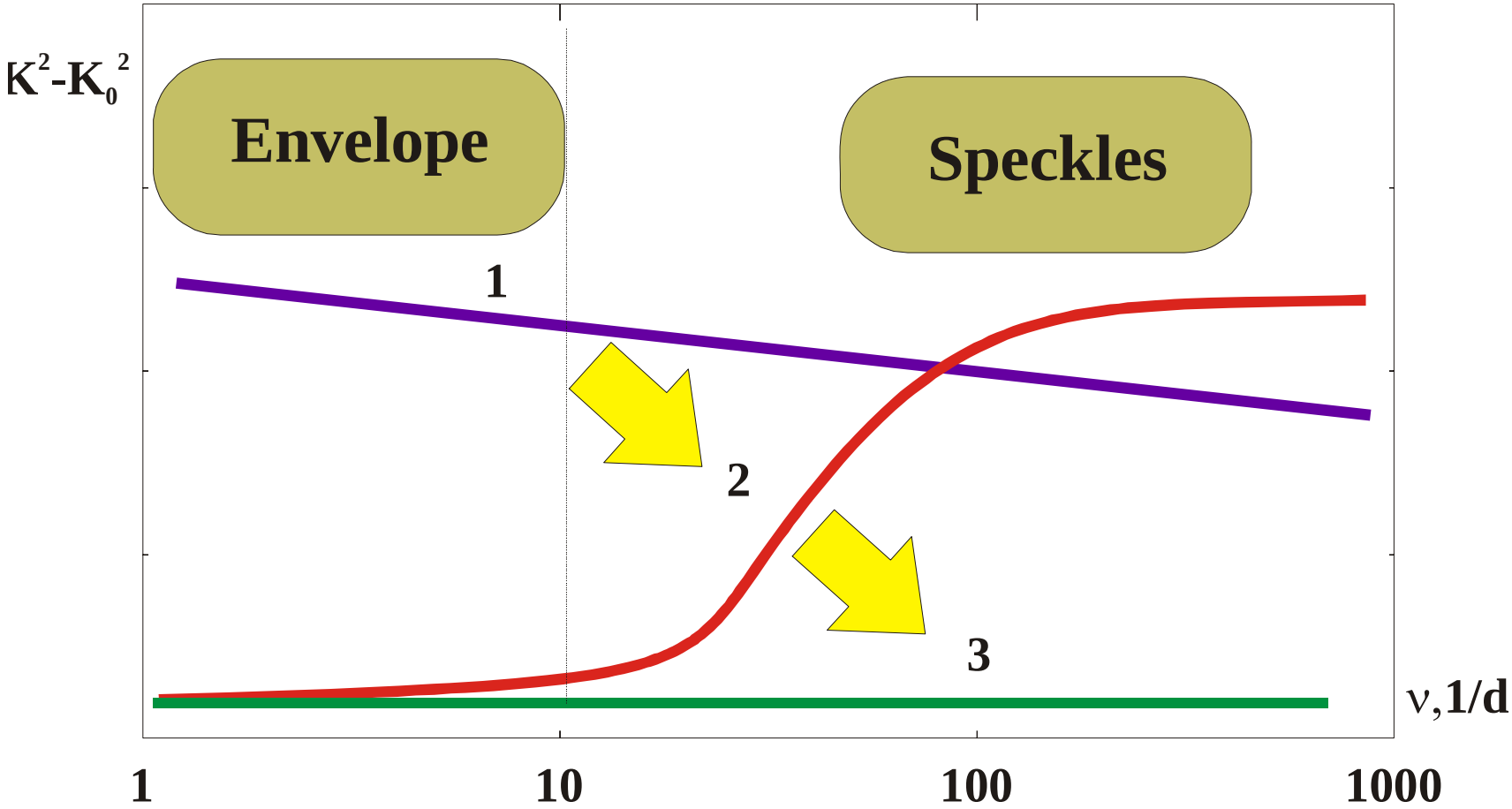
- **Concept of laser beam smoothing**
- **Novel types of lens raster's for beam shaping**
- **Plasma induced smoothing for speckles suppressing**
- **Recent experiments results**

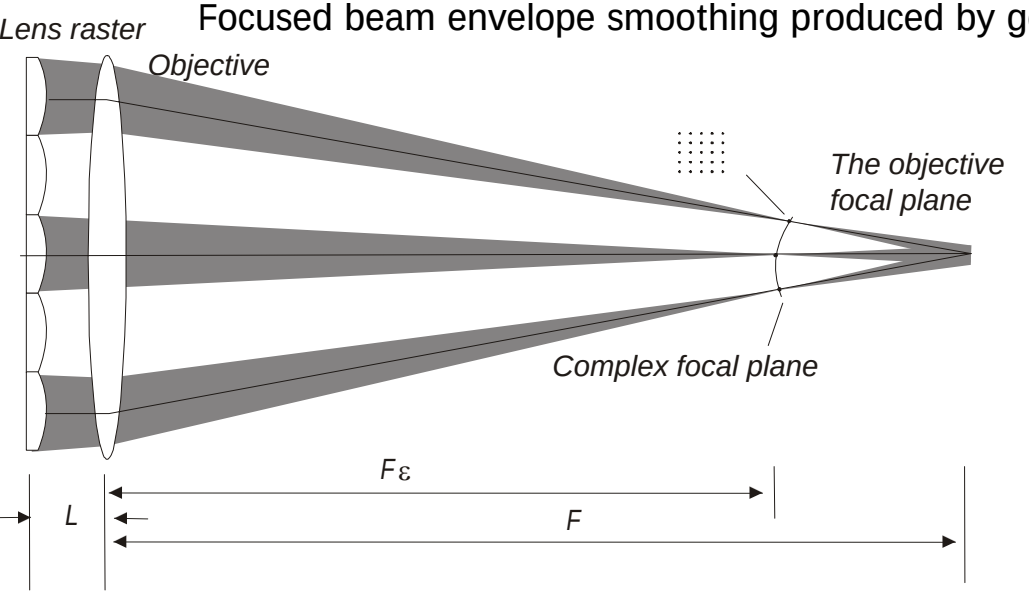
Beam smoothing principles



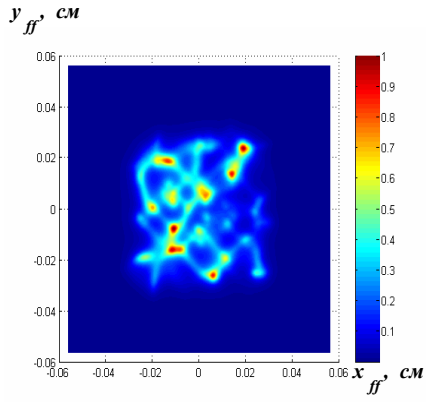
1 - aberrated laser beam
2 - stationary smoothed
3 - temporally smoothed

Lens array for beam shaping

Focused beam envelope smoothing produced by geometrical factor: $U = U_{initial} / N_{1D}$

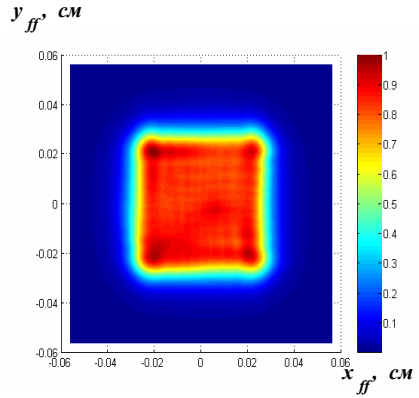


initial beam



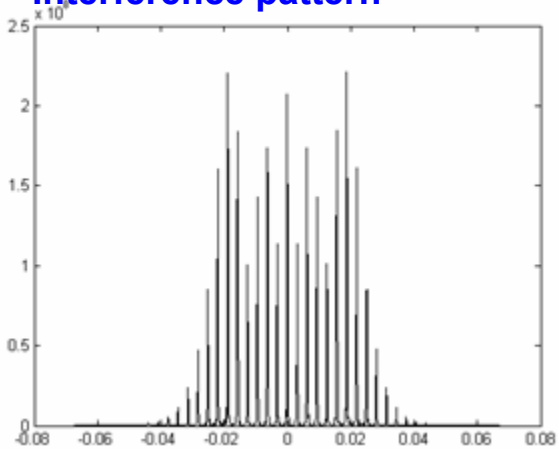
N=1

smoothed by raster

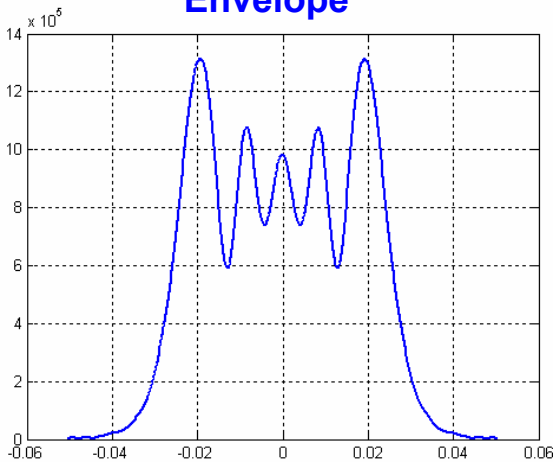


N=8

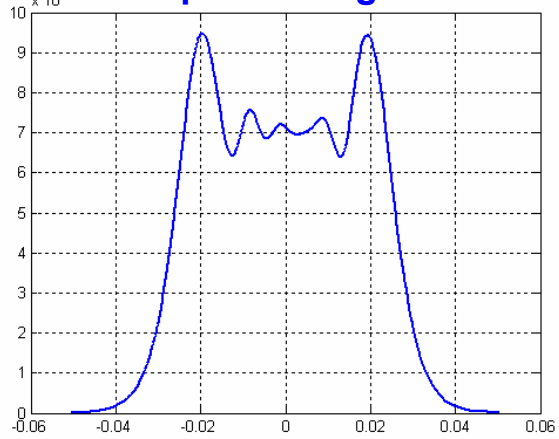
Interference pattern



Envelope



Envelope + divergence



<u>The basic features of a standard raster:</u>

Uniform spot size – 2/3 from the geometrically determined

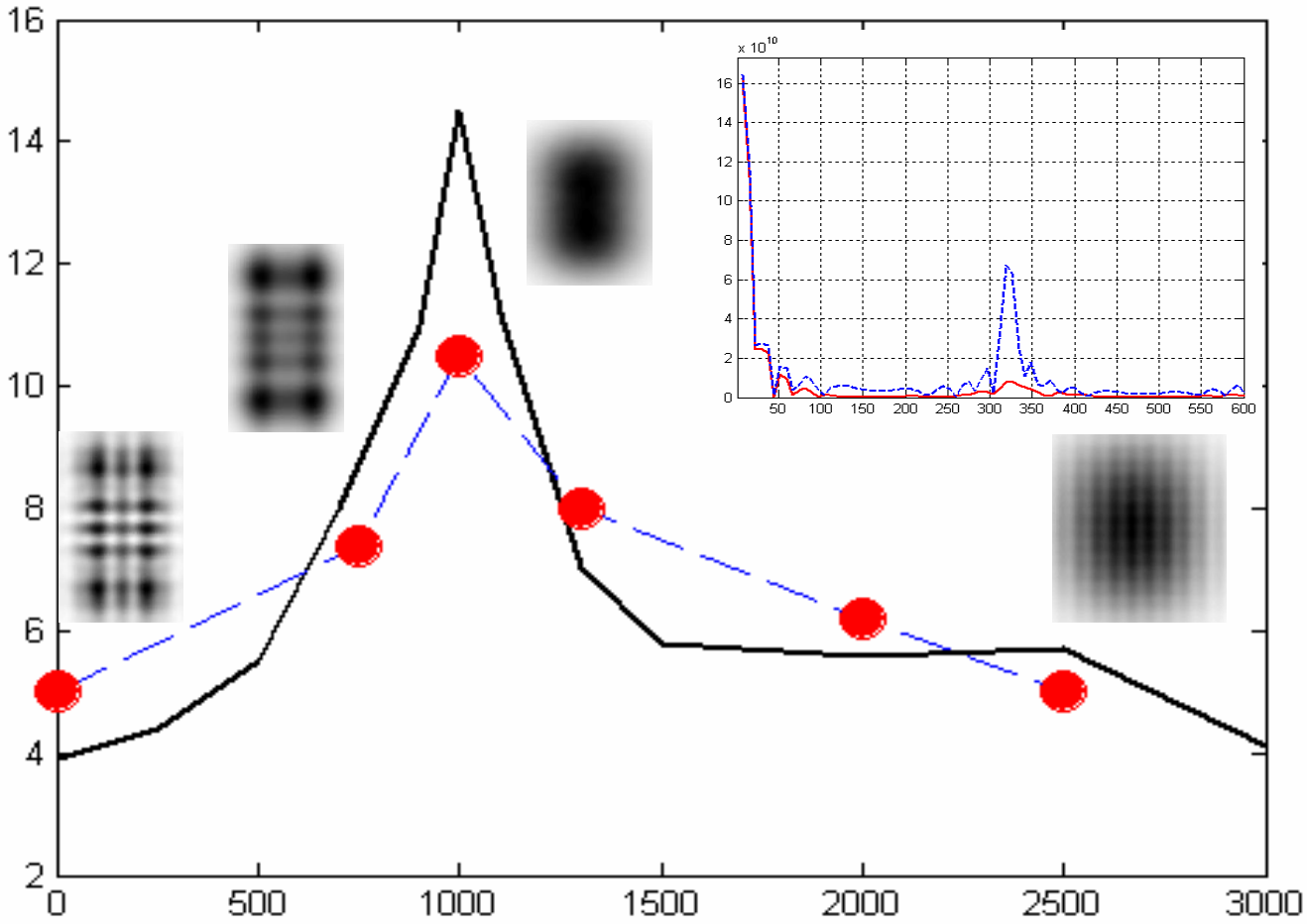
Energy concentration ≈50%.

Raster optimization

- Variation of focal spot configuration (square to rectangle)
- Choosing the divergence to compensate the diffraction pattern
- Edge softening by serrated apodizer
- Determination of the complex raster configuration with mutual diffraction compensation

Beam quality vs induced divergence

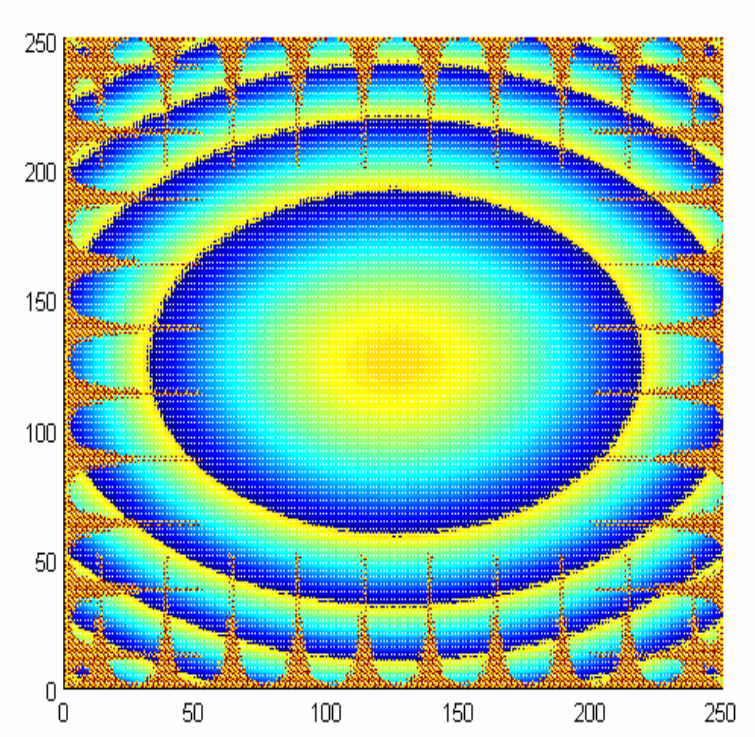
$\eta = E_S / U_S$

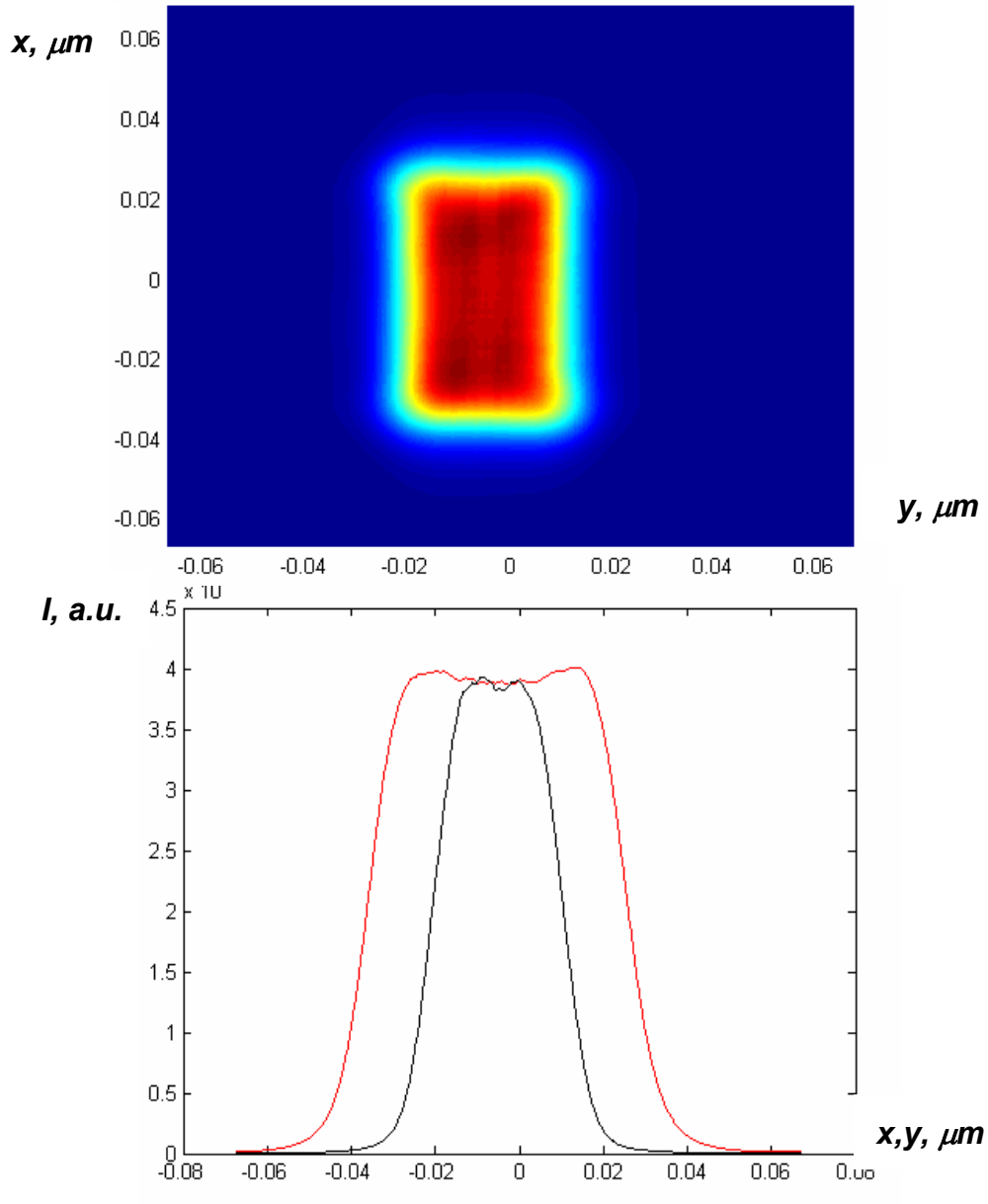


$\Delta Z, \theta$

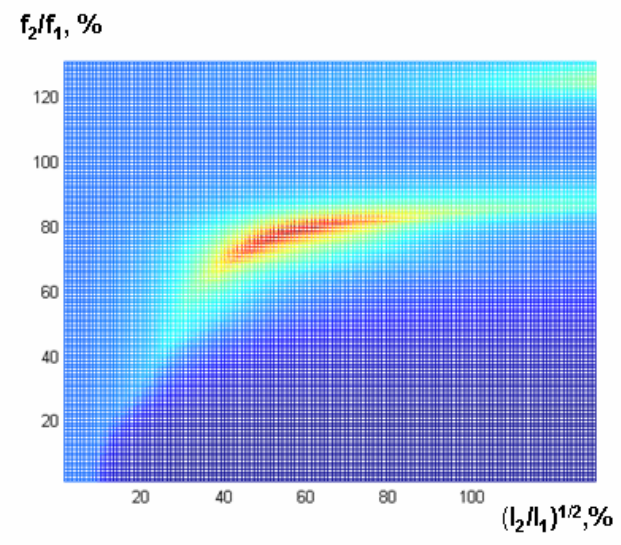
Edge softening

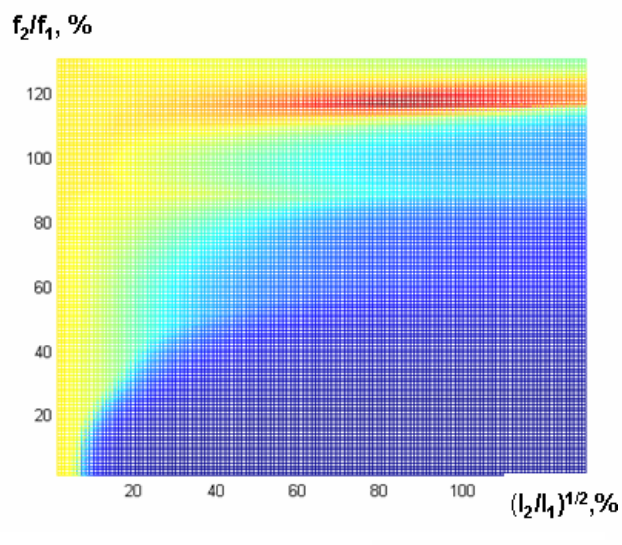
Raster cell topology

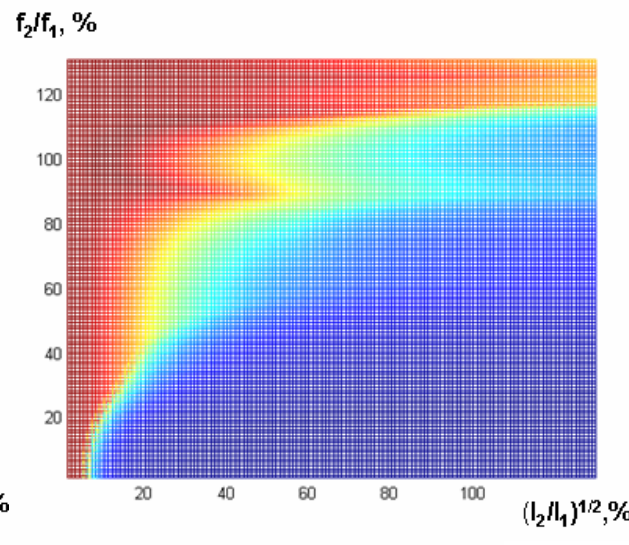




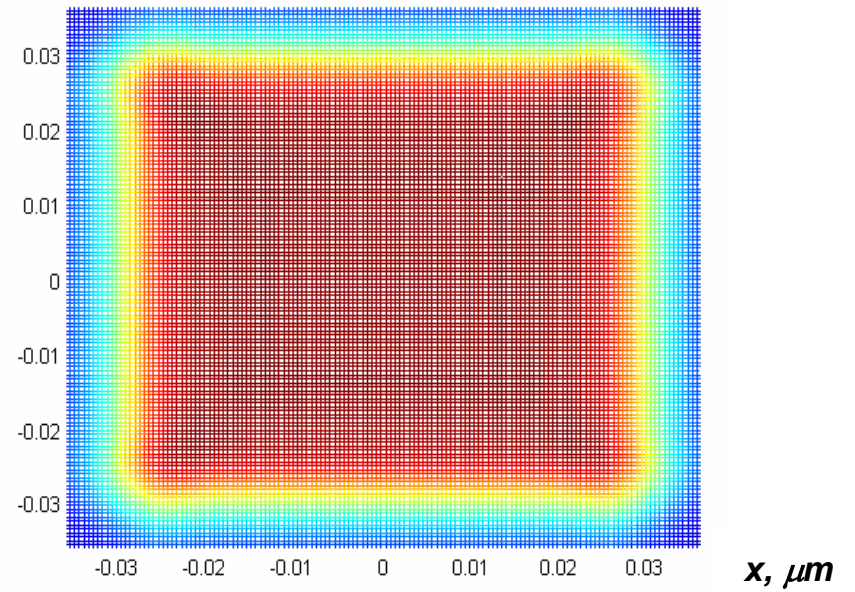
Multi component lens raster





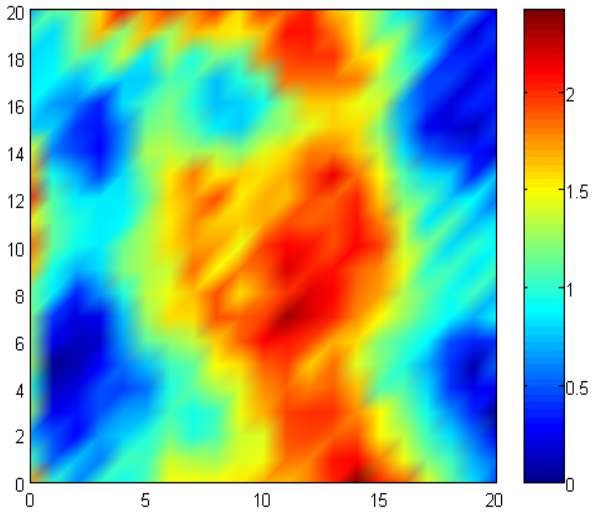


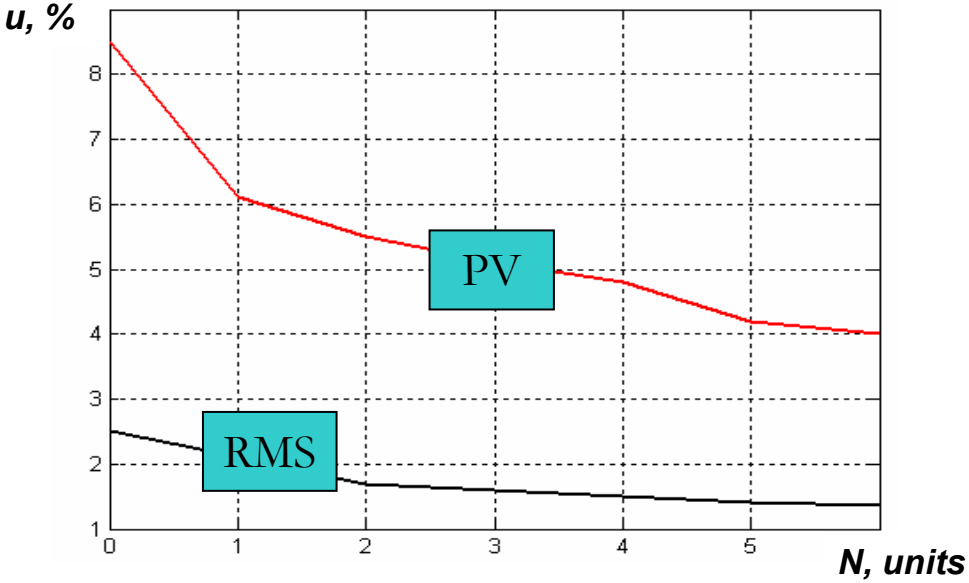
	1 type	2 type	3 type
Square, %	35,91	6,21	57,88
Number of elements	23	4	37
Focus distance, m	41,667	56,306	34,722



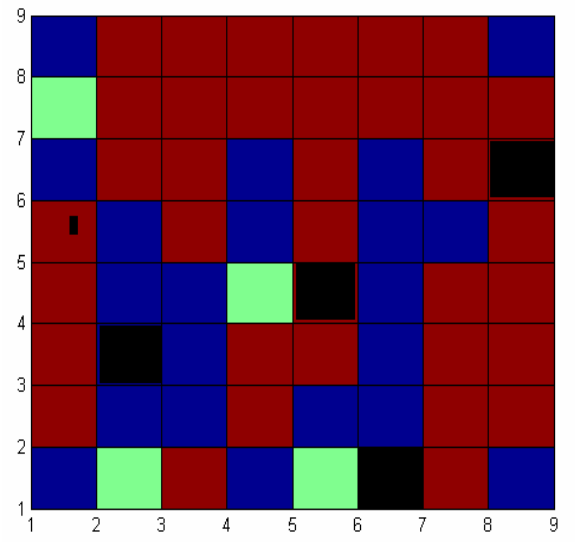
Operating with beam quality

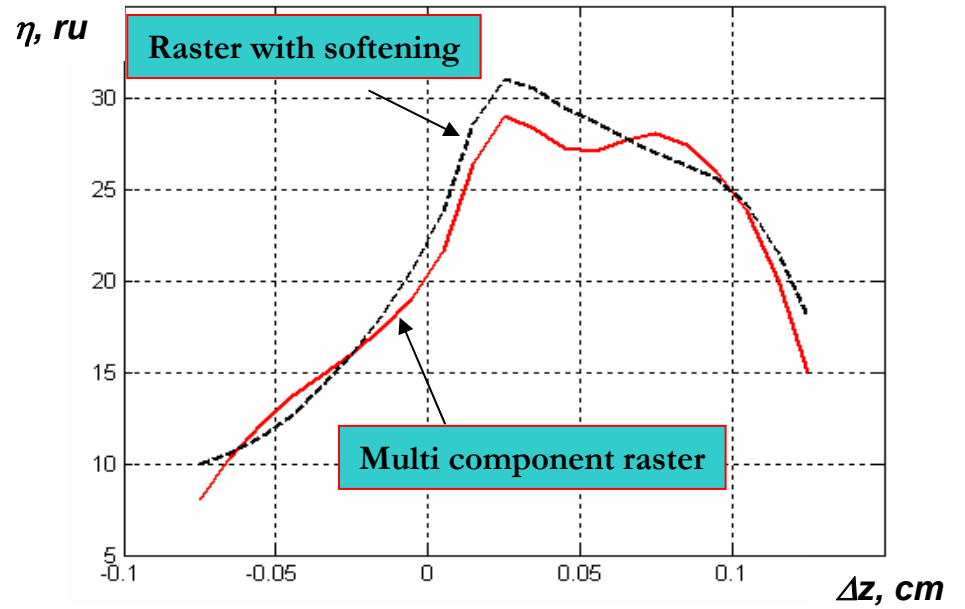
2D wave front simulation



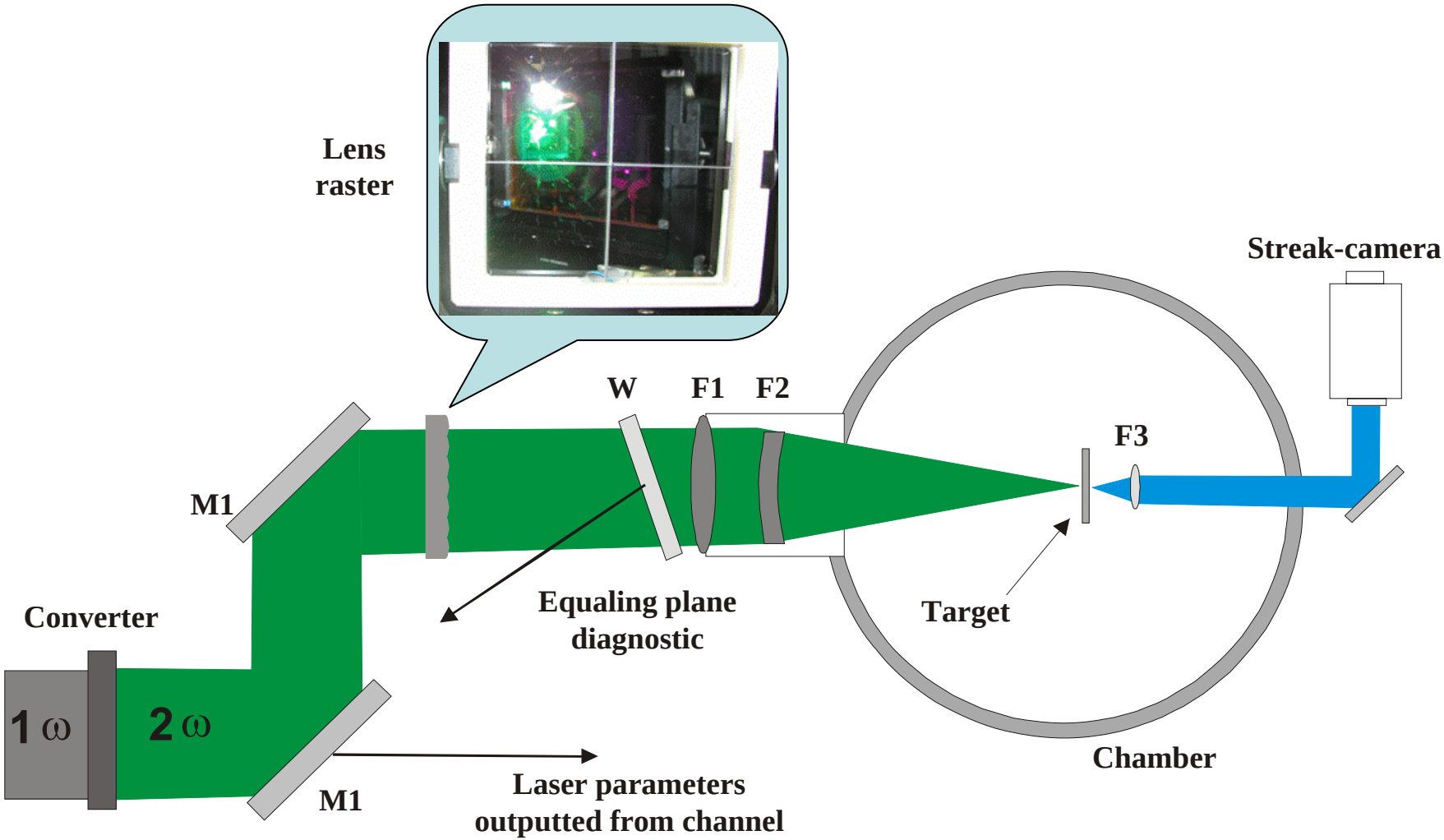


Raster topology

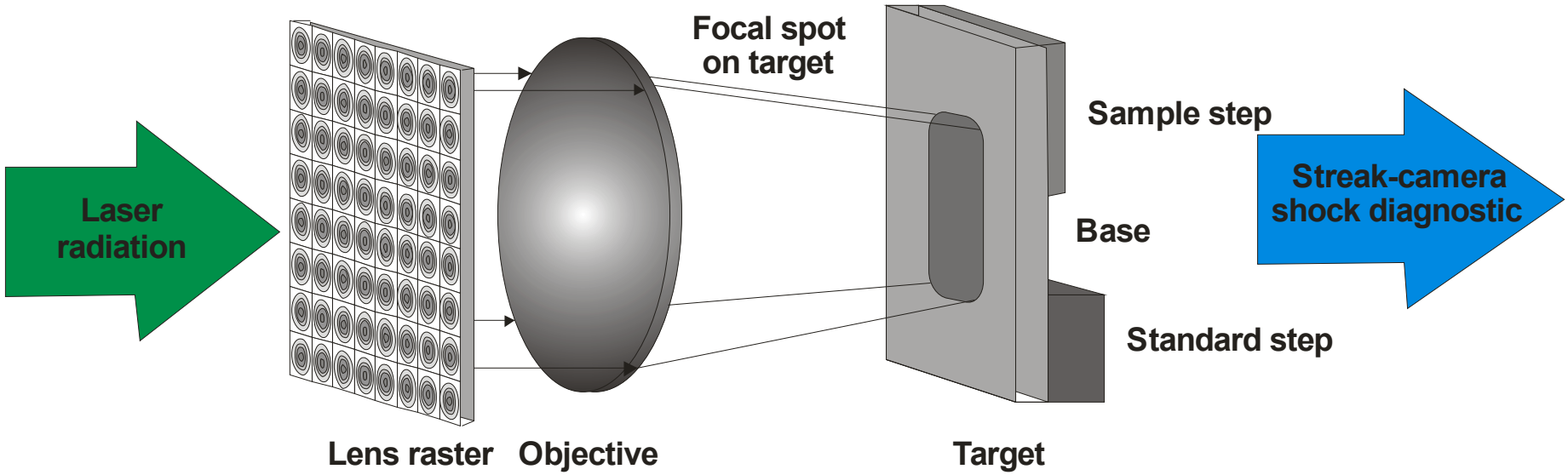




The EOS experiments on LUCH



Parameters of experiments



Laser parameters:

- *Wave length 0,527 μm;*
- *Energy 150-600J;*
- *Pulse duration 2 ns;*
- *Contrast >10^7;*
- *Intensity $5 \cdot 10^{13}$-$2 \cdot 10^{14}$ W/cm^2*
- *Beam size on target 600x300 μm^2*
- *Uniform area of beam 400x200 μm^2*

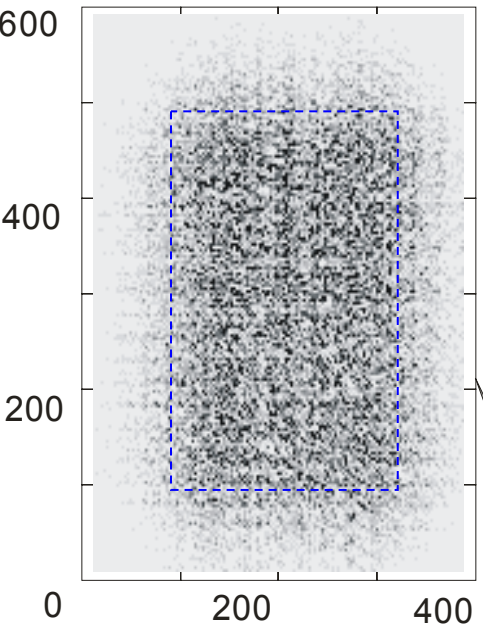
Target parameters:

- *Base: plastic (6-8 μm) & Al (50-100 μm);*
- *Steps materials: Al, Cu, Pb;*
- *Steps heights: 5-30 μm;*
- *Steps crown: <0.1-0.2 μm;*

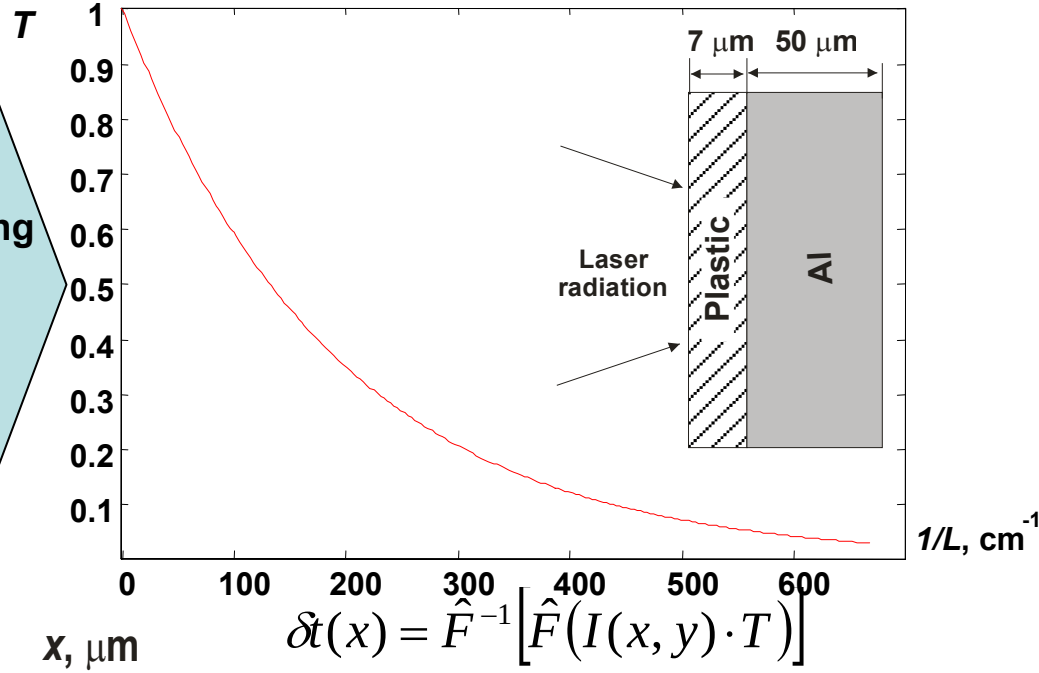
Diagnostic performance:

- *Optical magnification 5.5;*
- *Spatial resolution <10 μm;*
- *Temporal resolution <10 ps;*
- *Accuracy of the delay determining <10ps*

Shock uniformity experiments

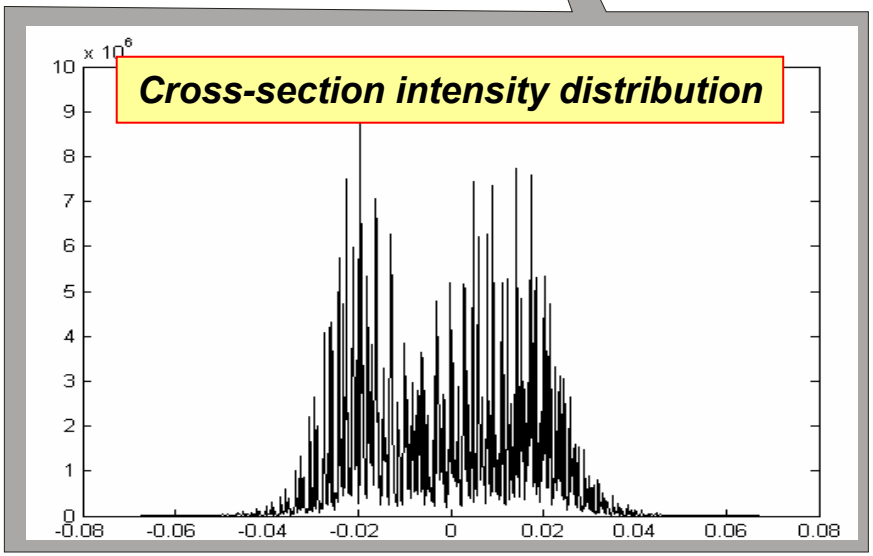


T – shock smoothing by target hydrodynamics

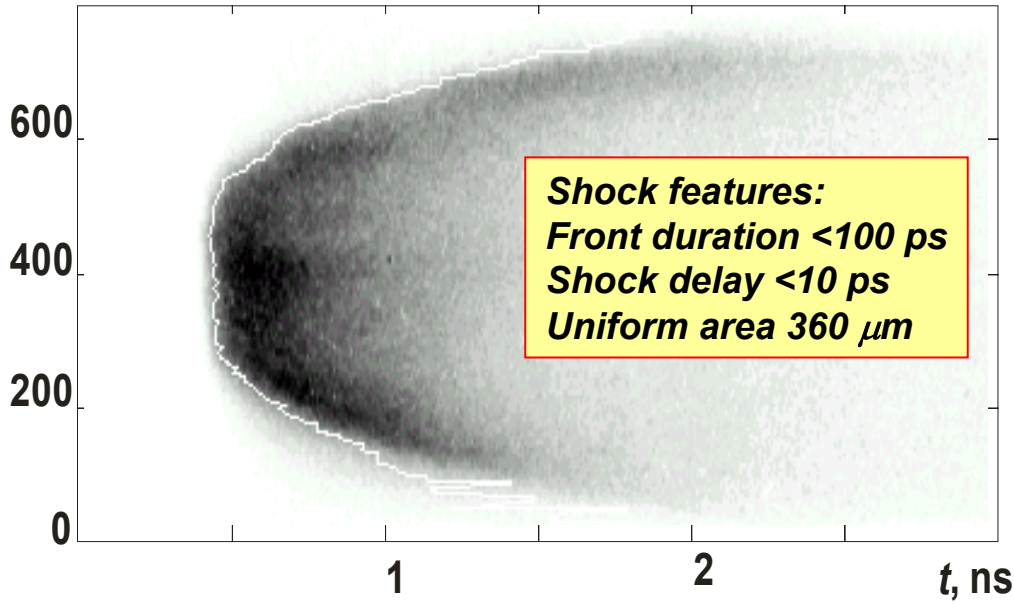


$$\delta t(x) = \hat{F}^{-1}\left[\hat{F}\left(I(x,y)\cdot T\right)\right]$$

x, μm

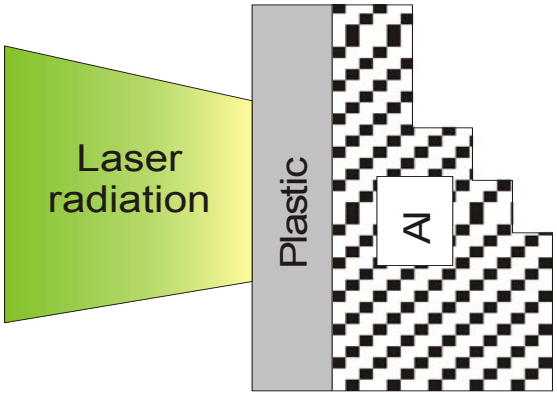


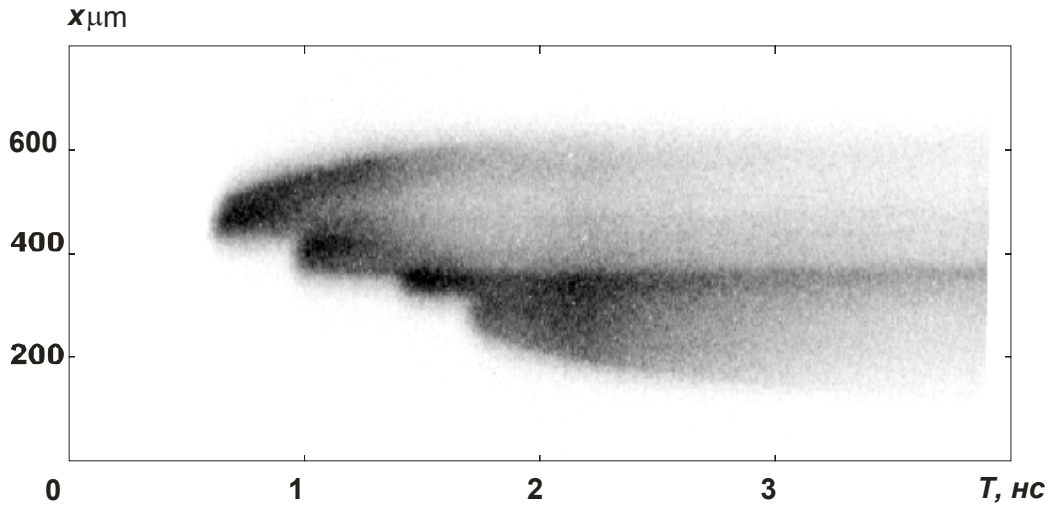
Cross-section intensity distribution

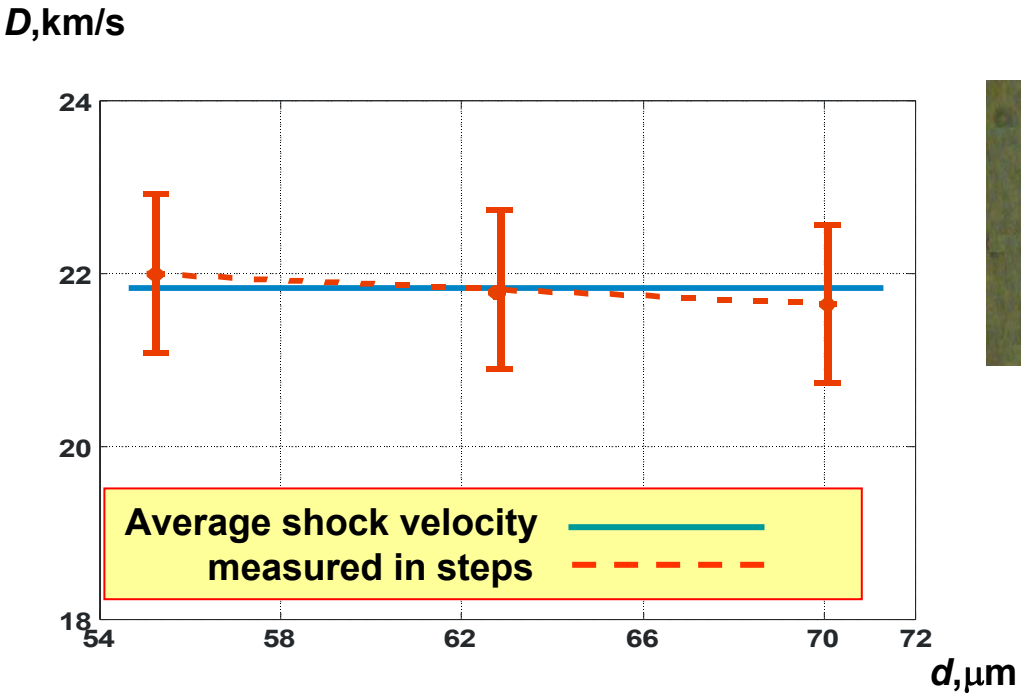


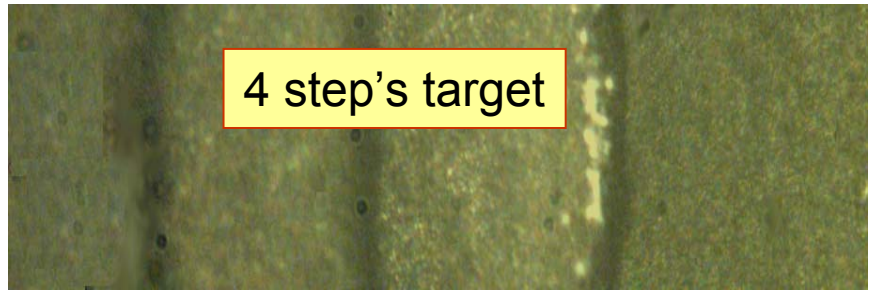
Shock features:
Front duration <100 ps
Shock delay <10 ps
Uniform area 360 μm

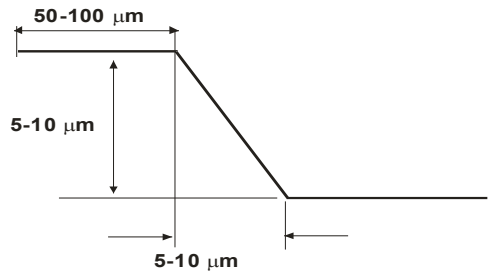
Experiment on shock stationarity



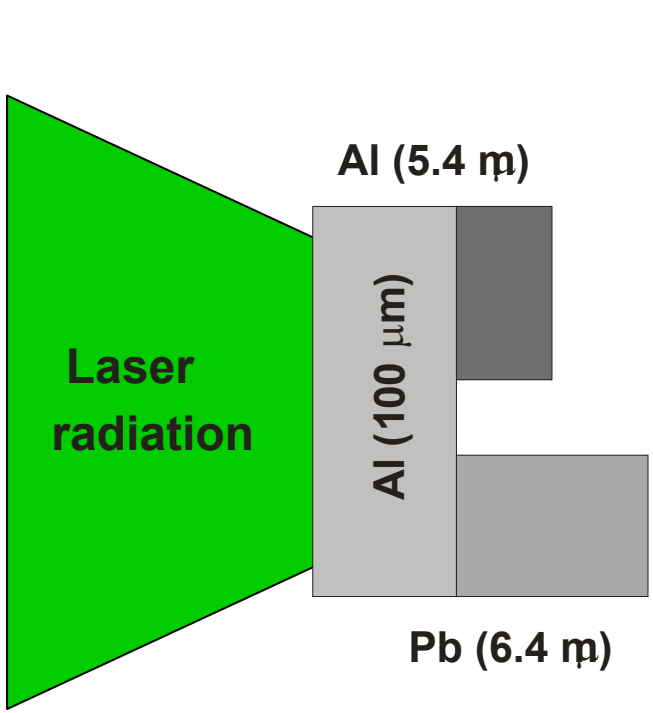


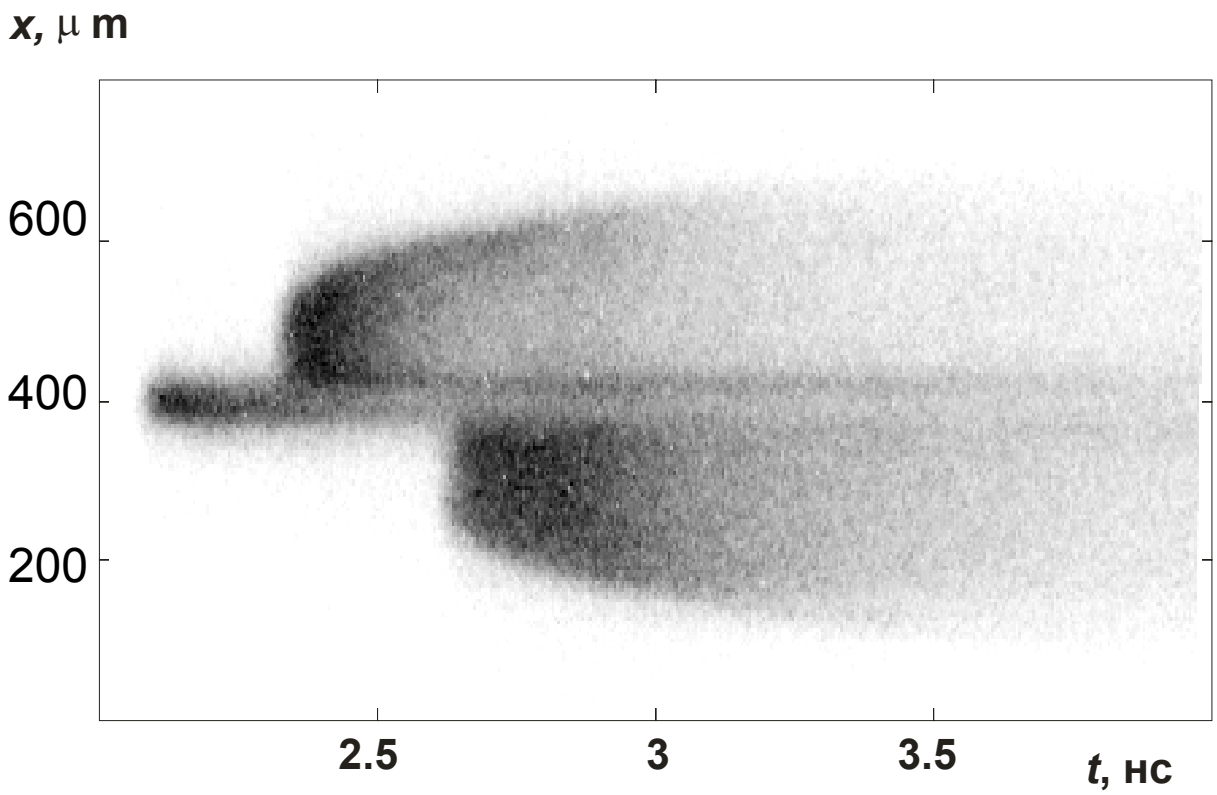






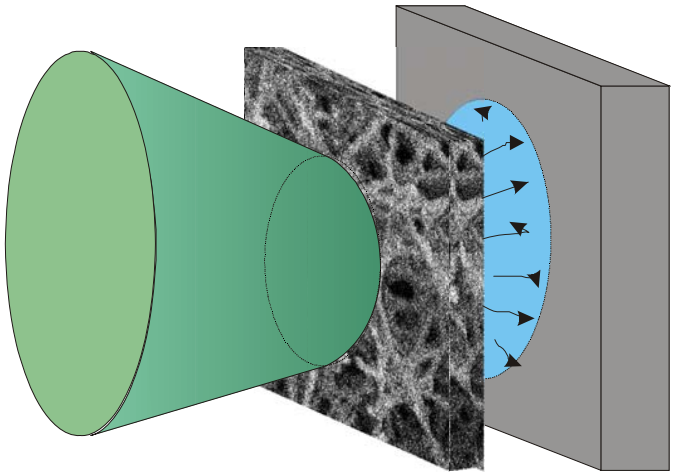
Investigation of the EOS of Pb





EOS perspectives on LUCH facility

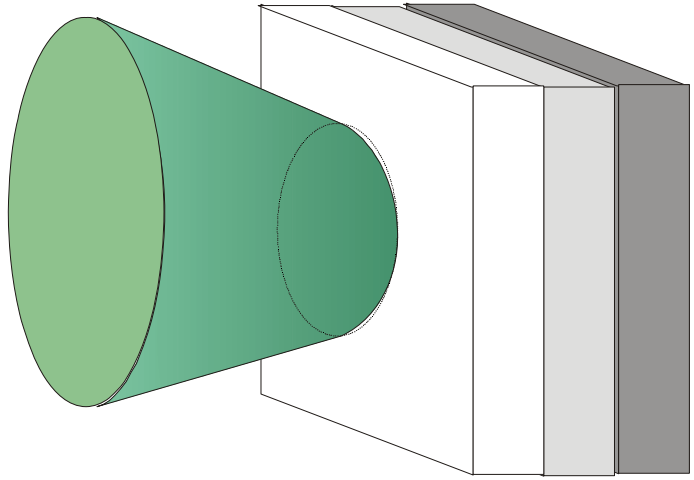
Beam quality should be increased with undercritical foam smoothing



Undercritical

Laser Foam Target

Pressure should be increased to 100 Mbar with targets having the profiled density



Overcritical

Laser Foam Plastic Target

Feather steps:

- ***Intensity smoothing by multi-focus lens raster applying***
- ***Works on target perfection***
- ***Revision of EOS of Cu and standard changing from Al to Cu***
- ***Temporal resolution increasing***
- ***High-Z materials testing***
- ***Introduction of active shock diagnostic***

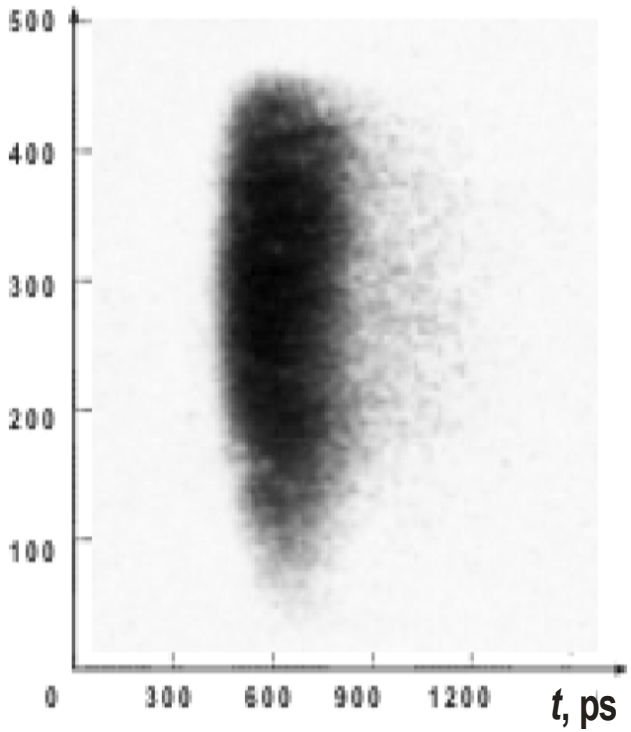
Plasma induced smoothing

Purpose: *reducing of laser induced shock nonuniformities by temporal smoothing of laser spot irregularities . Method concludes in laser coherence reduction when passing through undercritical plasma layer. The dynamical plasma phase plate method is found to have great efficiency:*

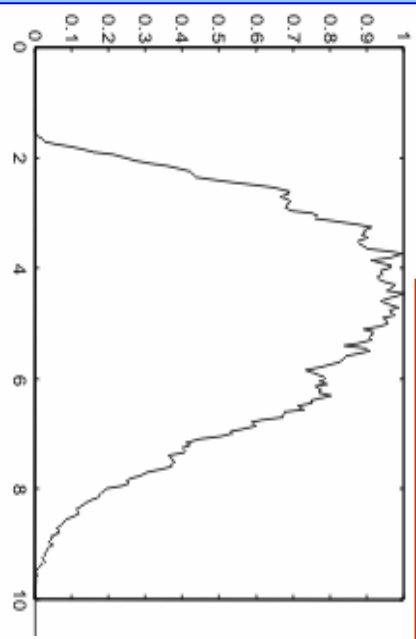
- *Energy transition >80%*
- *Nonuniformity <3%*
- *Speckles redistribution 0.4 ps*
- *Smoothing duration >300 ps*

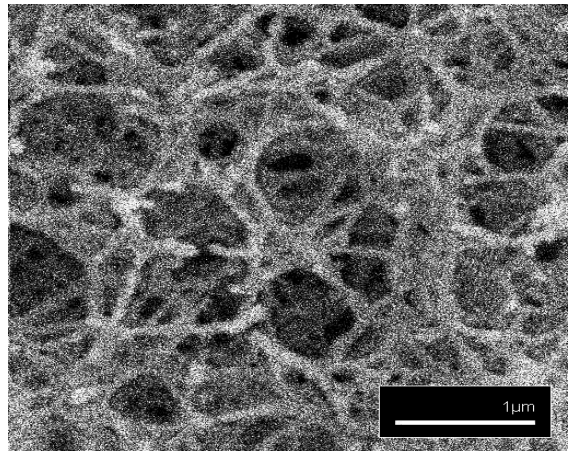
DPPP smoothed beam

Streak-camera image



Cross-section intensity integral (over the pulse duration)





Undercritical foams advantages:

Smoothing starts with front of pulse;

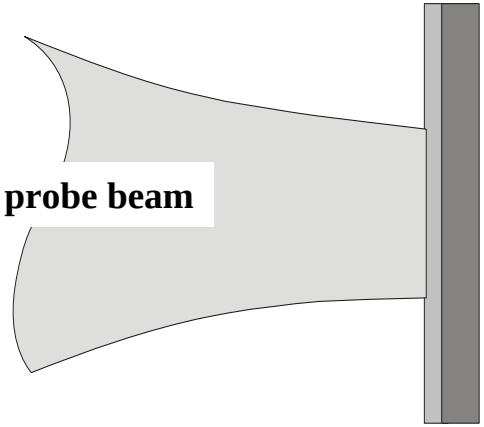
- *Smoothing duration increased to ≈1 ns;*
- *Efficiency increased of scales smoothing towards several hundreds microns.*

Experiments started with foams:

- *Density 1-2mg/cm^3 & thickness 100-200 μm*
- *Transition is achieved ≈60% and >80% is forecasted*

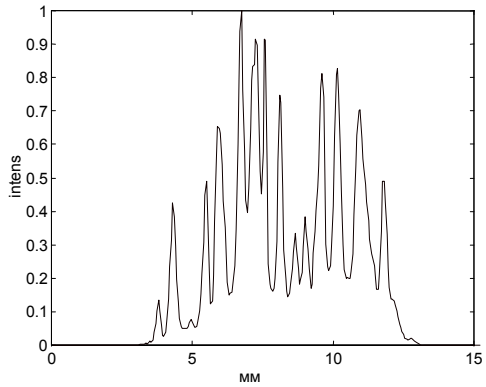
Dynamic plasma phase plate experiments

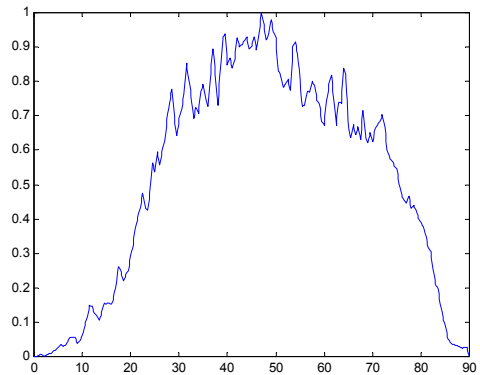
Unsmoothed probe beam



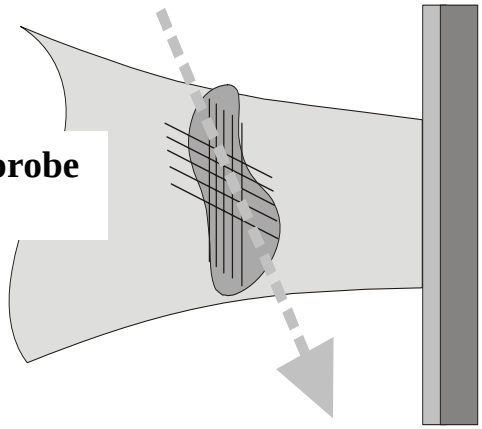
Au (0.1 μm)/Al

Cross-section of a far-field distributions



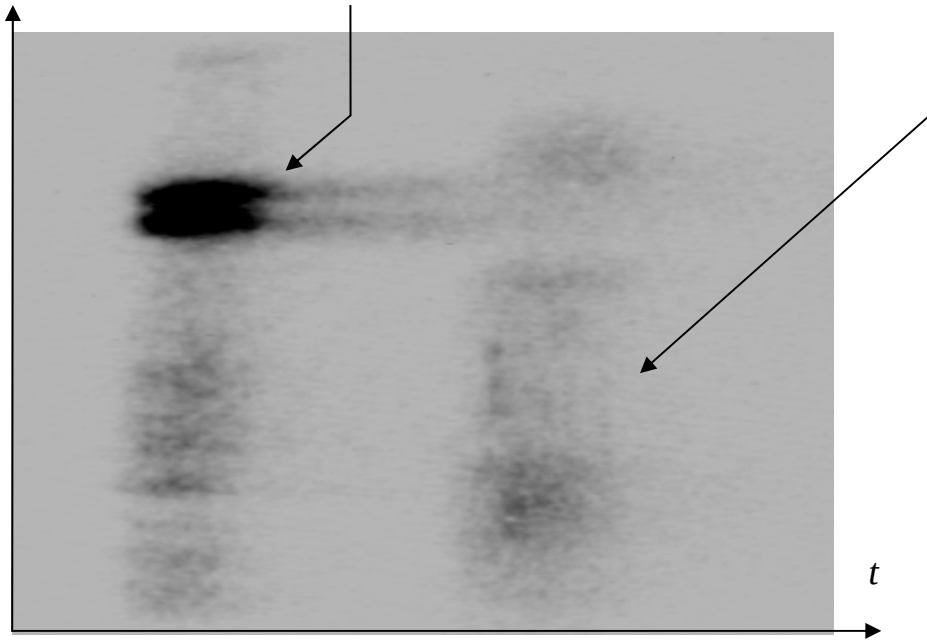


Smoothed probe beam

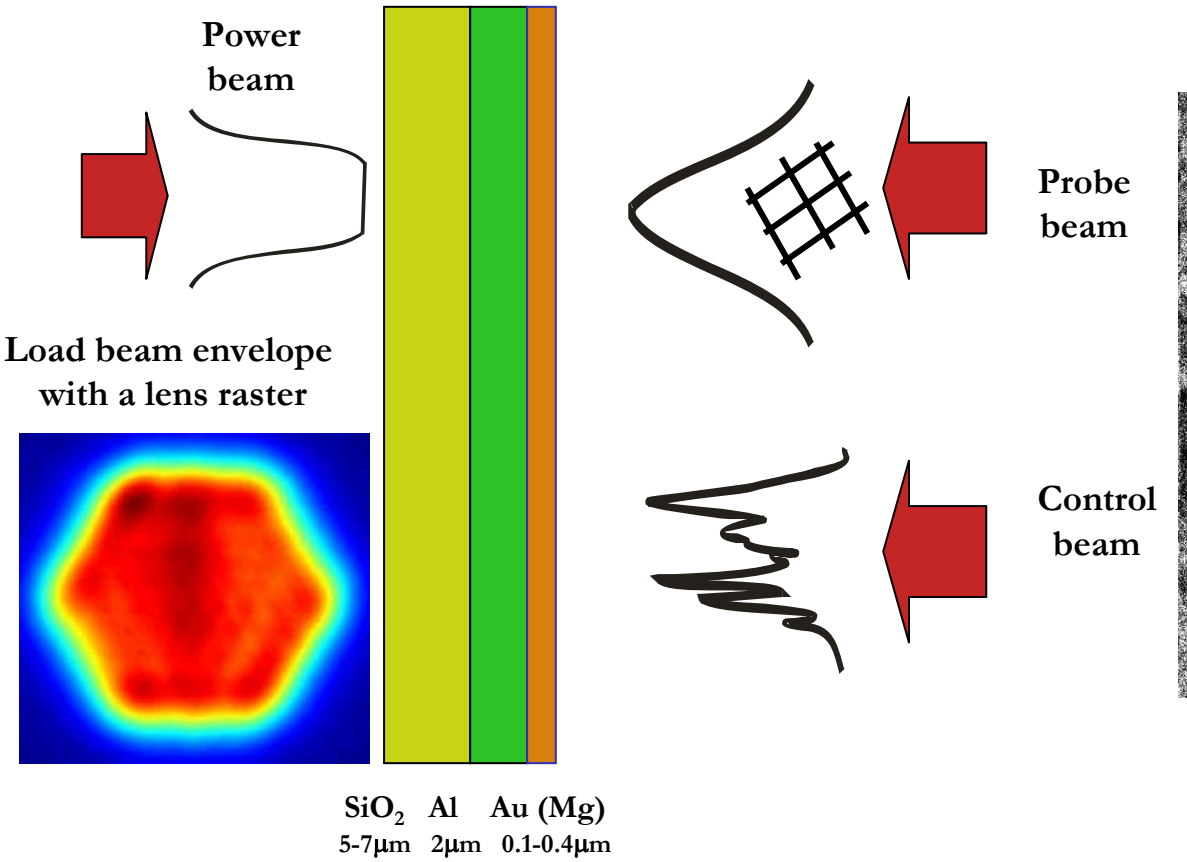


Nonstationary plasma cloud
(dynamical plasma phase plate)
initiated by special pulse ahead the probe at 300 ps

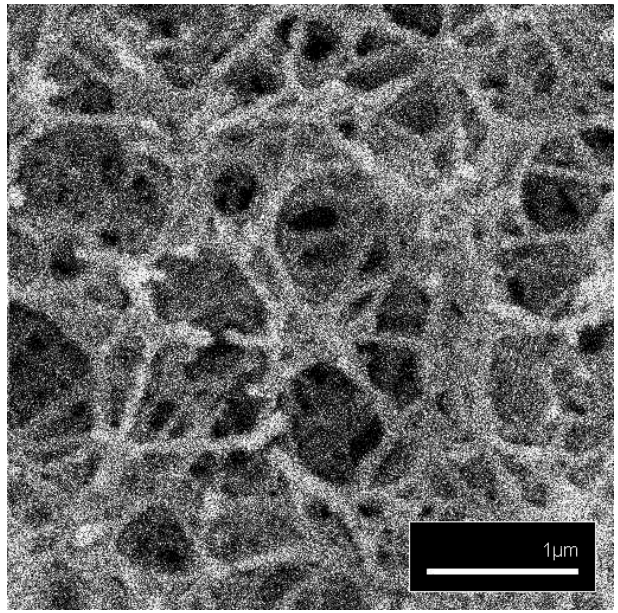
Registration of spectrum: Au continuum and He(α) of Al



Experiments on turbulent mixing



3D foam target for smoothing



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