Laser Interactions with Low-Density Foams at PALS

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In collaboration with
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History

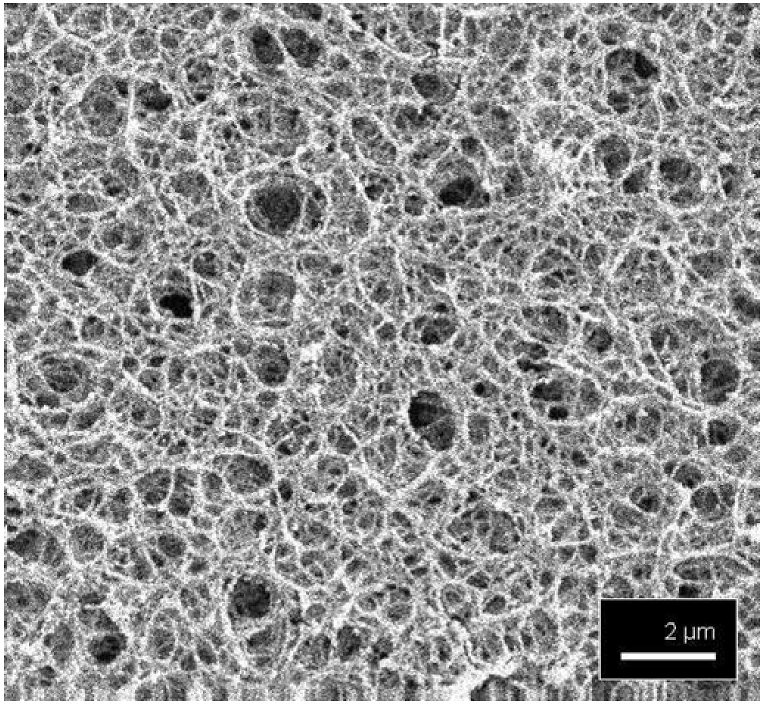
- Interaction experiments with low-density foams were started at PALS in 2002 for the partial fulfillment of the project
  INTAS - 01- 0572 "*Plasma creation, energy transport and smoothing of non-uniformities in volume-structured media irradiated by high-power laser pulses*“ (1st June 2002 - 30th May 2005 - Czech-Russian-Italian collaboration)
- First experiment started in early 2002 – *Polish group lead by A. Kasperczuk and T. Pisarczyk joined the experiment*
- Experimental campaigns in 2003, 2004, 2005 and after project completion continued in 2006 and 2007

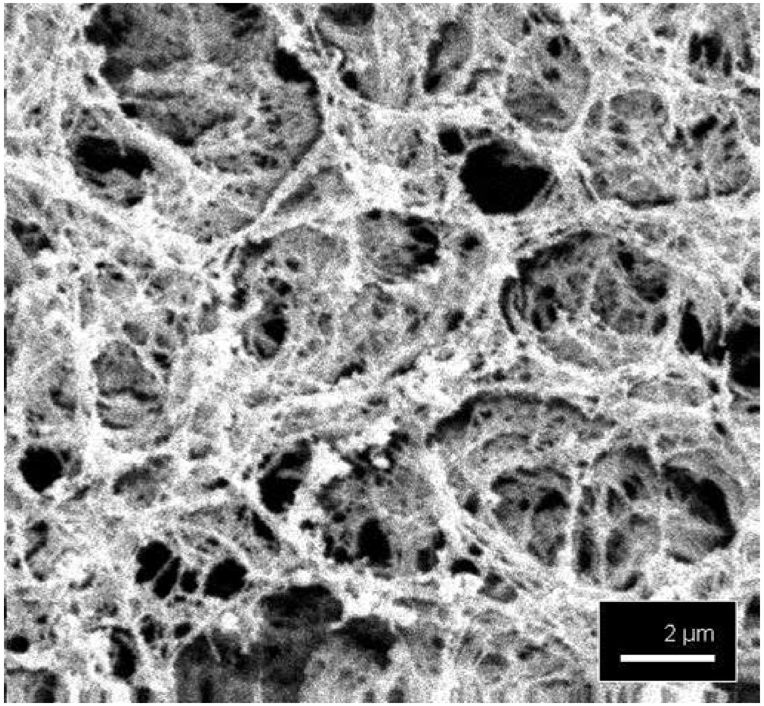
Aim

- Study direct laser interaction with sub- and supercritical foam with small (~1 μm) and large (> 10 μm) pores
- Study energy propagation in foam (ionization hydro-thermal wave)
- Study foil acceleration by the pressure of heated foil
- Study laser transmission through underdense foam
- X-ray spectra measurement from doped plastic foam

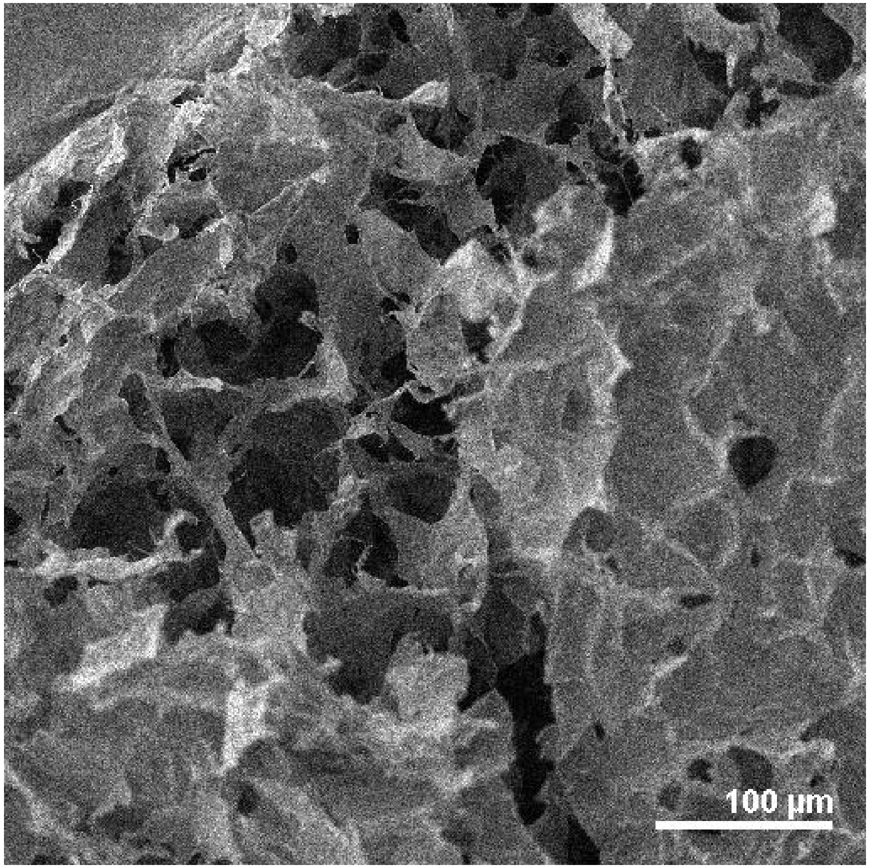
Foams with open cells (3D networks)

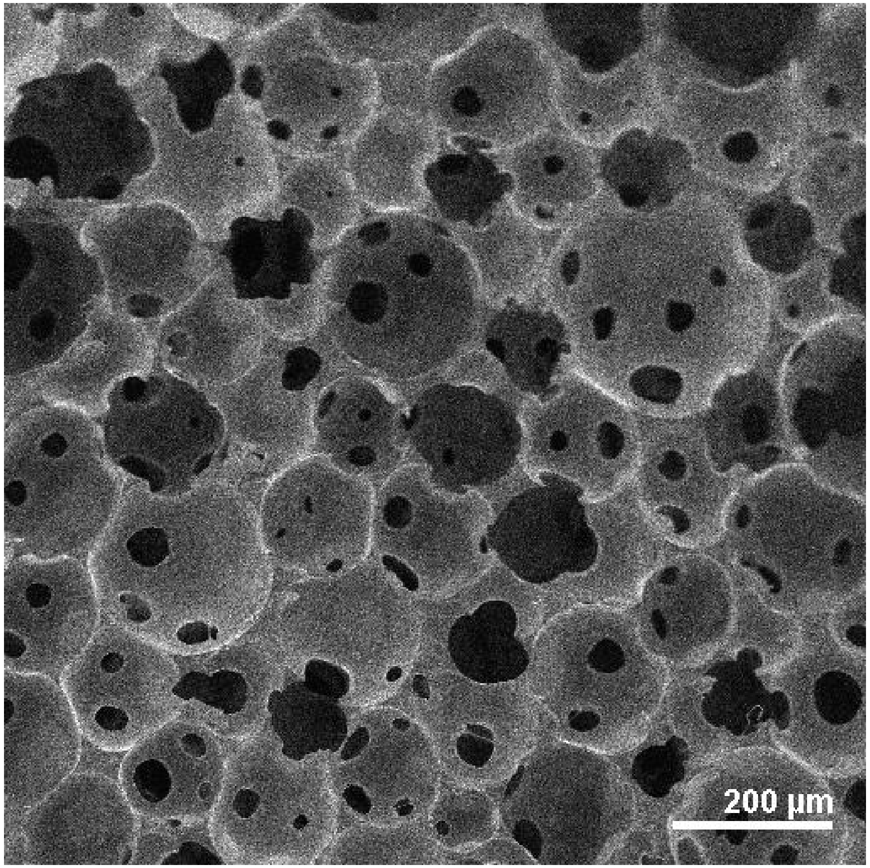
- Small-cell plastic foams without and with high-Z additions (Cl, Cu, SnO_2) - TMPTA (Nazarov), TAC (Borisenko)
- SEM microphotographs of TAC (cellulose triacetate) of density 9 mg/cm^3 - TAC pure and with 10 weight% of Copper, additions lead to structure roughening





Foams with large semi-closed cells

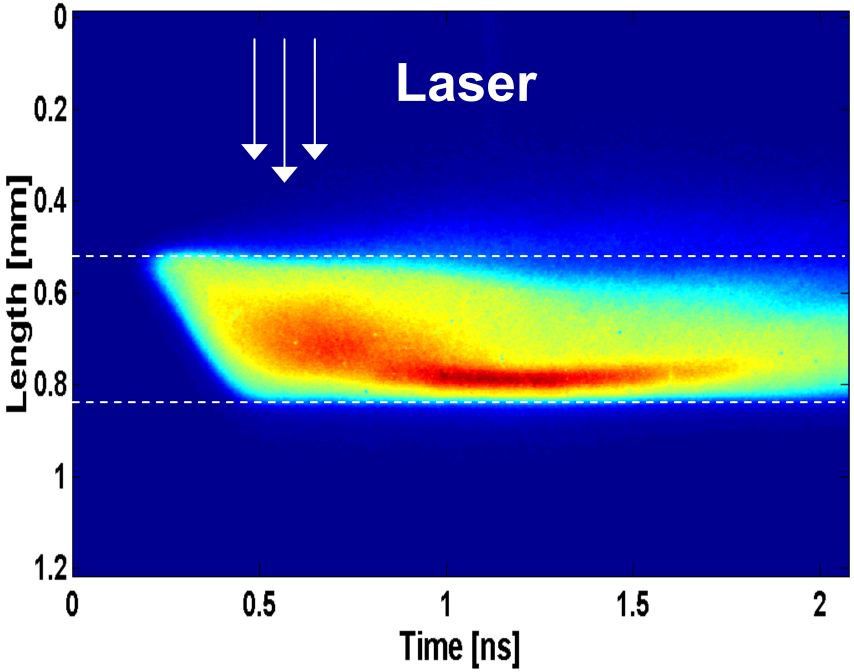


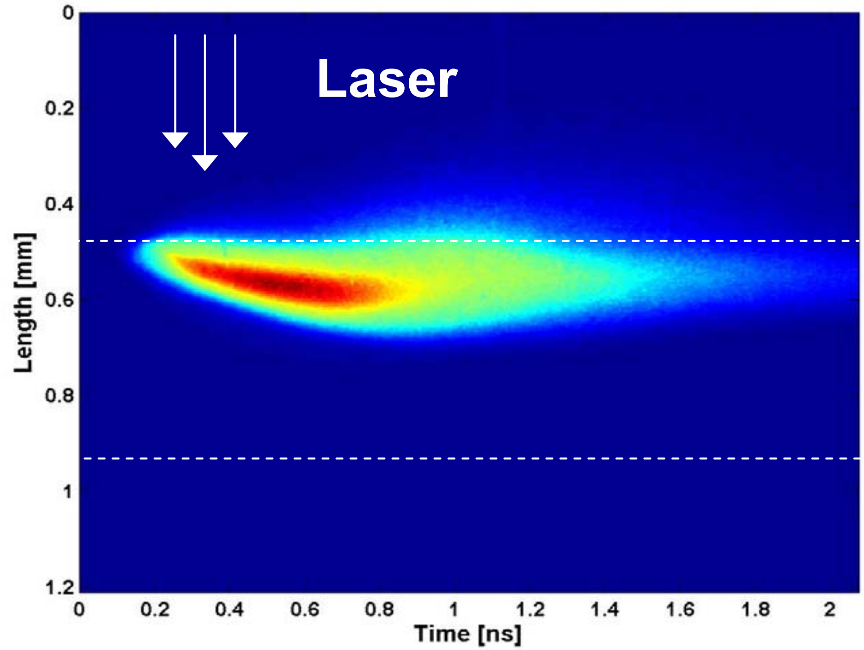


Agar-agar foam – 10 mg/cm^3

Polystyrene foam – 20 mg/cm^3

Energy transport in underdense foam with small (0.5–3 μm) and big (30–100 μm) pores



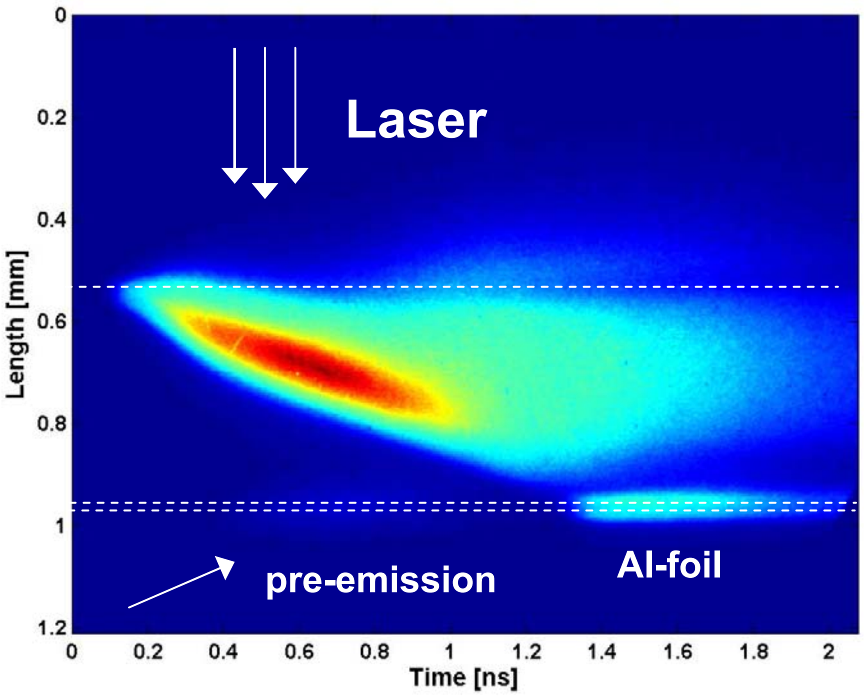


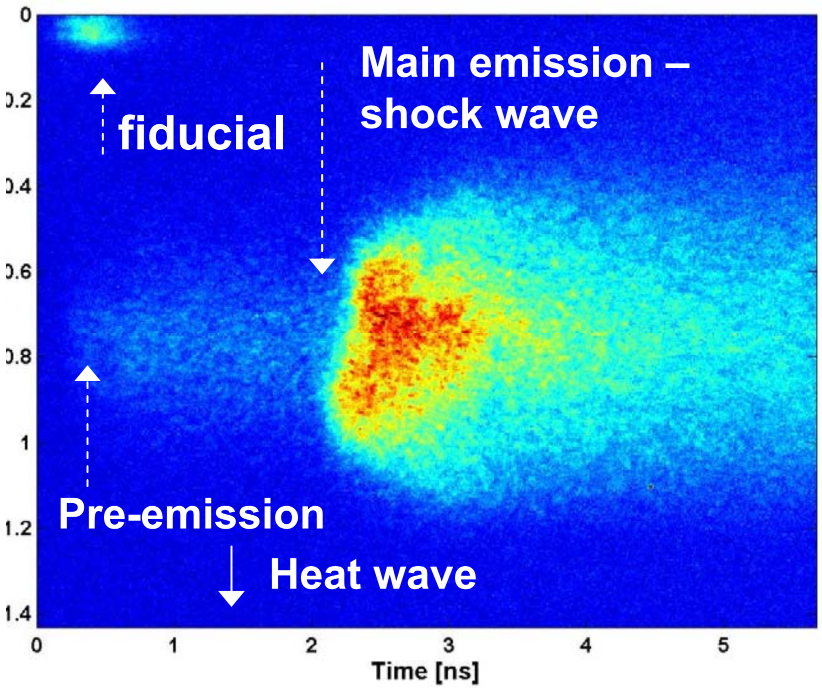
X-ray streak (side view)–laser 3ω, 320 ps FWHM, best focus above target, spot ∅ 300 μm, 5 μm Al at target rear side

small pore TAC 4.5 mg/cm^3 (=n_c/4), 380 μm thick,168 J, **fast** laser **penetration** 1.3±0.1x10^8 cm/s (4 similar shots)

big pore agar 5 mg/cm^3 (=n_c/4), 570 mm thick, 171 J, laser absorbed in 150 μm thick surface layer, **low penetration**

Denser ($n_c/2$) small pore TAC foam

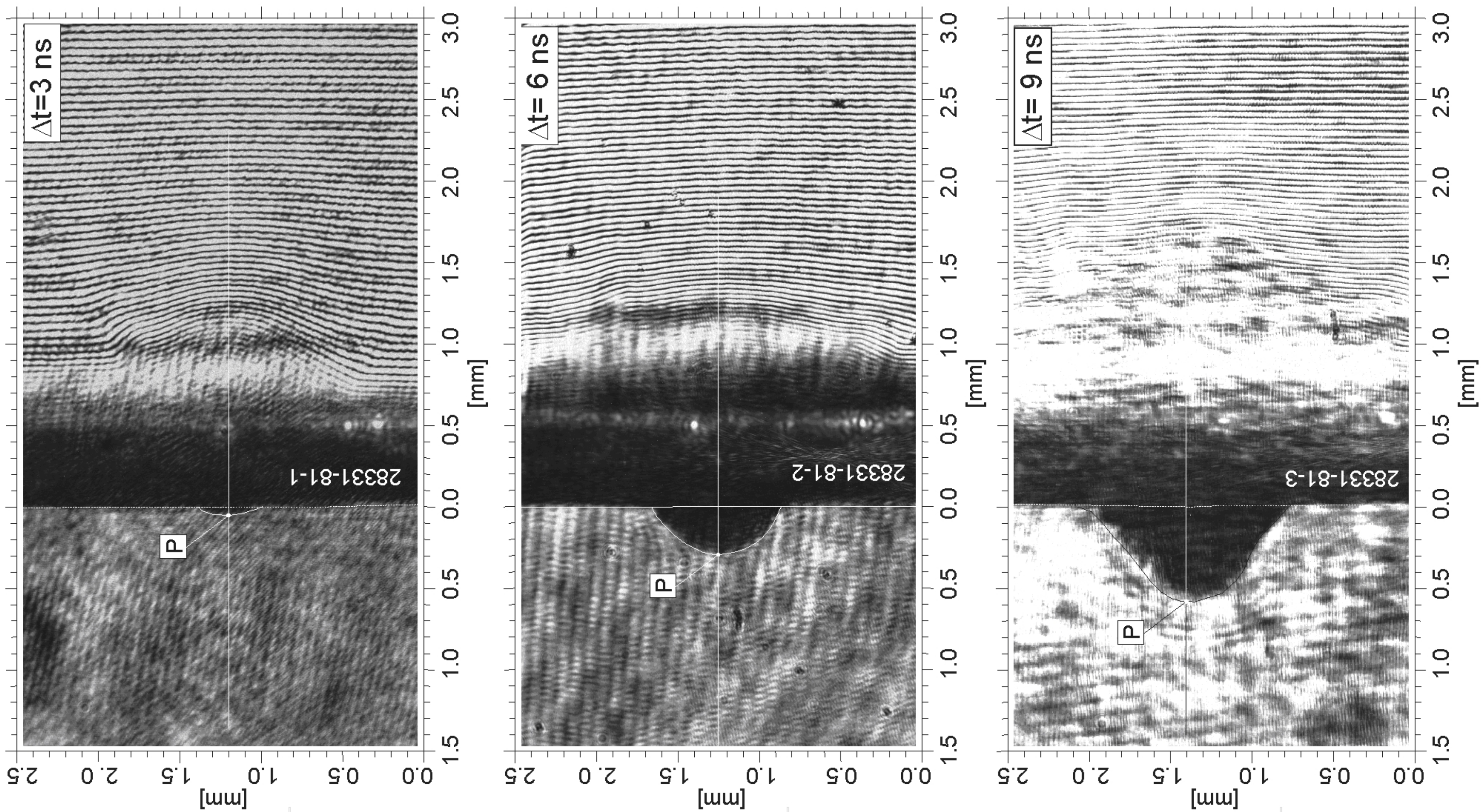




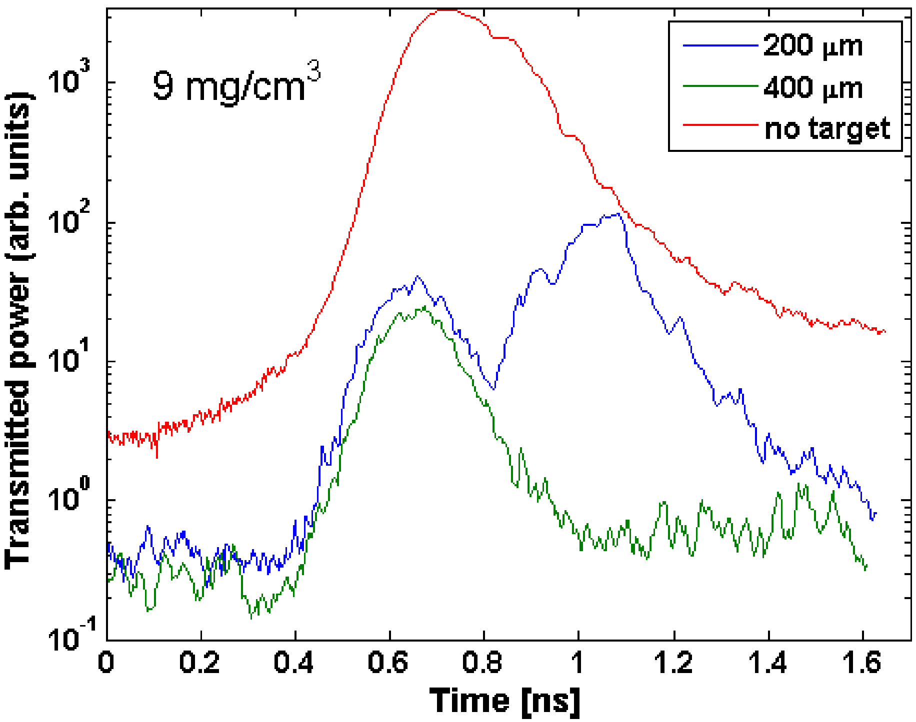
9.1 mg/cm^3, 400 μm thick, 5 μm Al at rear side, 3ω, 170 J, spot $\varnothing$ 300 μm, Left – side-on x-ray streak, Right – optical emission from rear side, fiducial (laser pulse) at top left

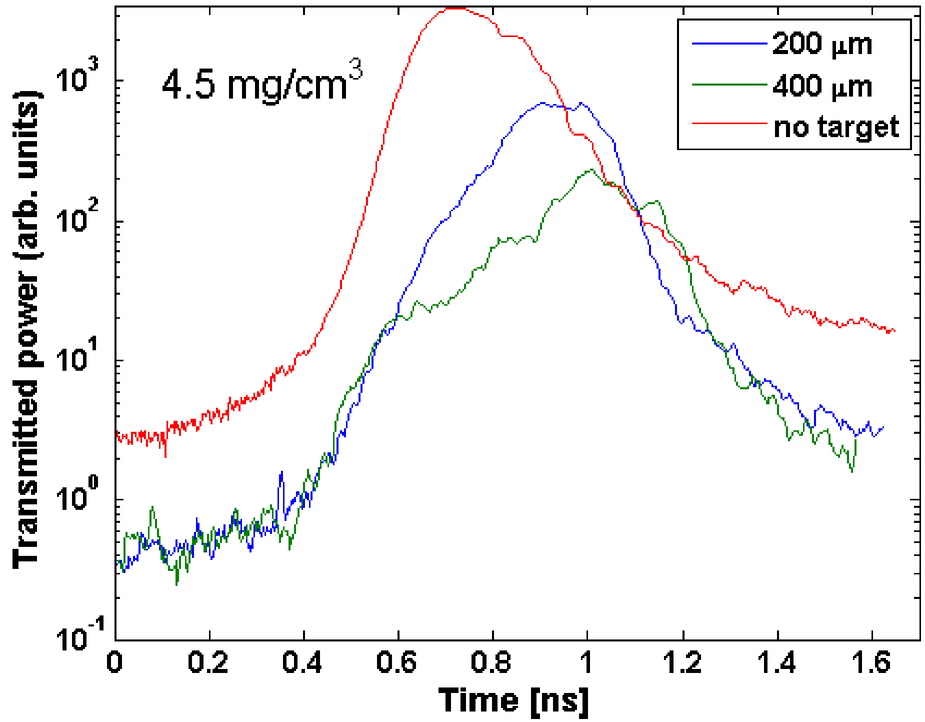
Small fast preheat – at the same time - optical pre-emission, thermal wave gets to rear side earlier than main opt. emis.starts

3-frame interferographs for 480 μm thick TMPTA foam 10 mg/cm^3+5μm Al, 3ω, 130 J



Temporal profiles of transmitted pulses



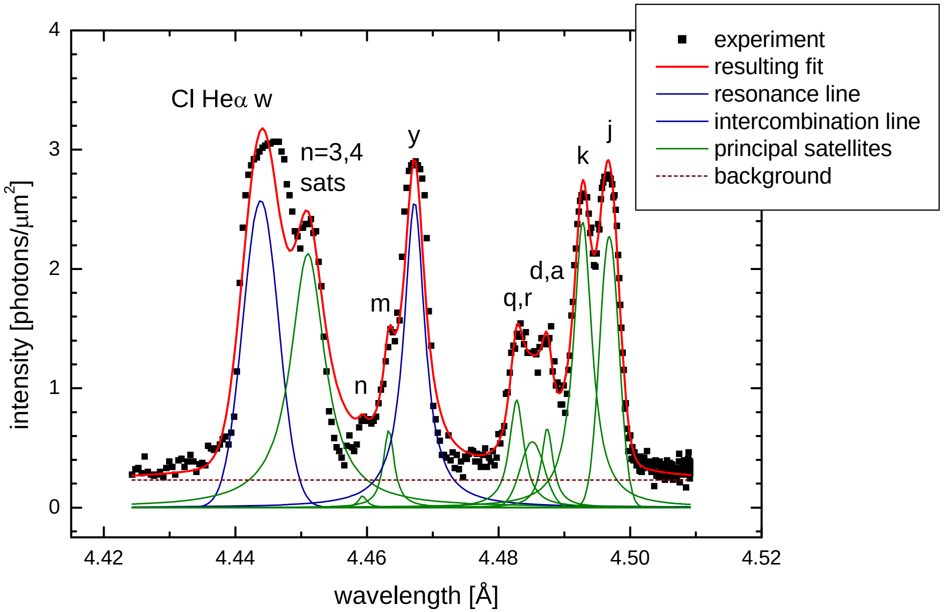


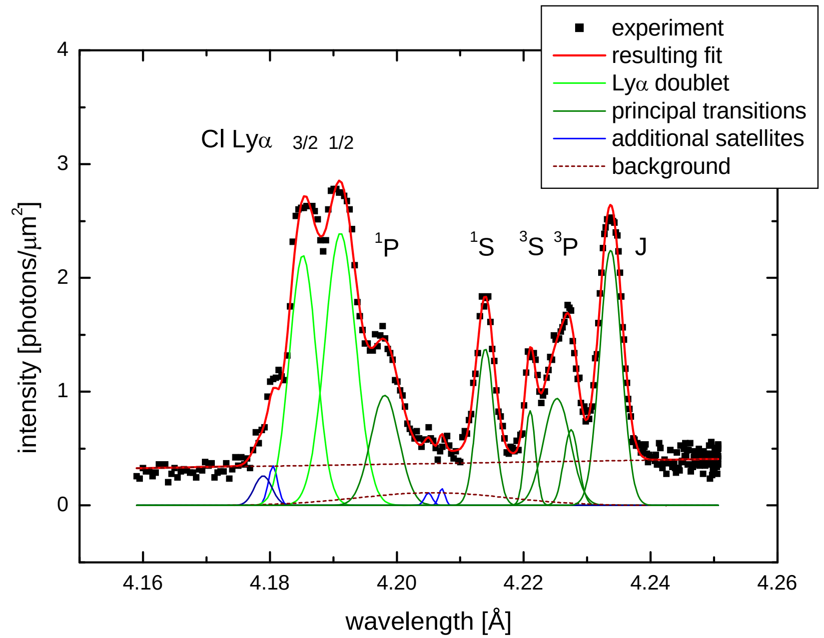
Laser pulses transmitted through foam as compared pulses propagated without foam

160 J, 3ω, TAC foam (pore size 0.5-3 μm)

Left – 9 mg/cc, right – 4.5 mg/cc

GA Based Analysis of Cl Heα and Lyα Spectra





Both spectra correspond to a distance 32 μm below the irradiated foam surface
spectral line identification in Heα group uses Gabriel's notation
satellites to Lyα doublet grouped according to final transition states

Renner O. et al, JQSRT 71 (2001) 623

GASPED derived intensities of individual spectral components provide input for the opacity-corrected version of the code FLY *Lee R.W. et al, JQSRT 56 (1996) 535*

Selected Macroscopic Characteristics of Heated Foams

Integrated volumetrically heated source emission (foam 10/20, focus -500):

Cl Heα res. line (E=2790 eV, ΔE=12.9 eV)	**1.1×10^{-2} J/4π**
	(2.58×10^{13} photons/4π)
Cl Lyα doublet (E=2960 eV, ΔE=10.6 eV)	**4.7×10^{-3} J/4π**
	(9.90×10^{12} photons/4π)

Laser light conversion efficiency into full Heα group: 0.02%

cf. reported 2% laser light conversion efficiency into x-ray broadband radiation 4.5-5.5 keV (3 mg/3% Ti-doped SiO_2 aerogel, 40 beams, 3-15 000 J, OMEGA laser, Rochester)

Constantin C. et al, Phys. Plasmas 12 (2005) 063104

Depth of the homogenously emitting plasma

varied in dependence on the focal position:

at 130 J, from 96 μm (target position -500) via 120 μm (0) to 136 μm(+500),

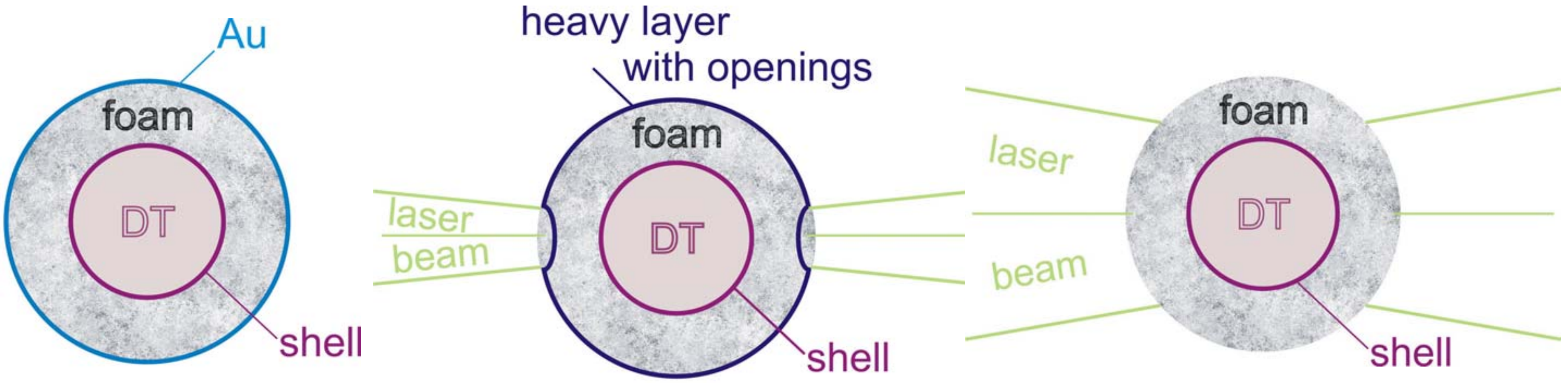
and increased with the laser energy (from 56 to 104 μm)

dependences on foam density were not decisive:

at low energies, penetration was largest for thinnest foam 10/20 (96 μm)

practically constant for high energies (88-104 μm)

Foams layers in targets for direct-drive ICF



Target for imprint smoothing
(*Dunne M. et al.* 1995)

Thin (~25 nm) gold foil for x-ray preheat to suppress early imprint of irradiation inhomogeneities

Foam layer to enhance ablation pressure smoothing

Greenhouse target (closed variant)
(Gus'kov, Rozanov 1995)

Aim is to minimize number of beams in reactor chamber

High voluminous absorption in thick foam layer
Ablation pressure smoothing
Outer layer to suppress expansion, intentional shell thickness variations assumed

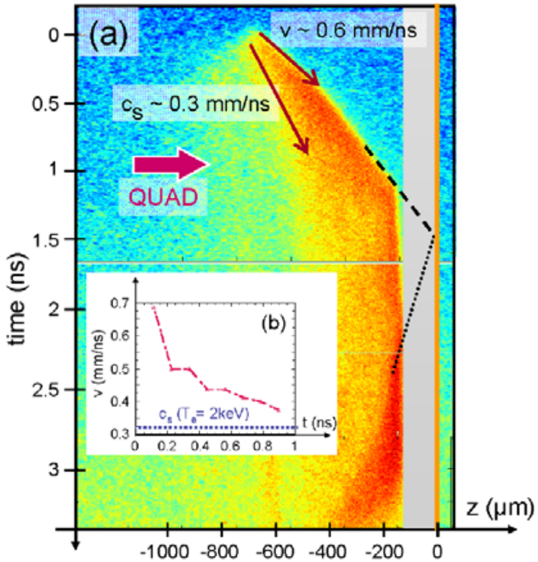
Greenhouse target (open variant)
(Rozanov 1997)

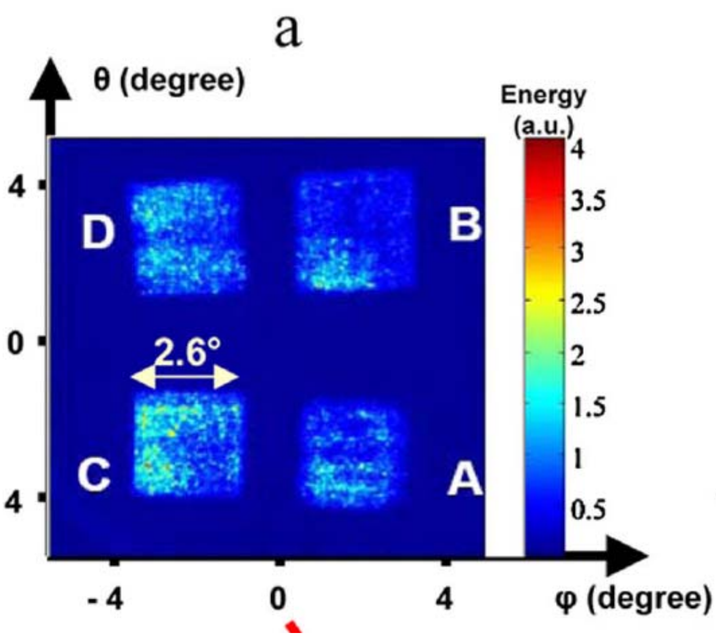
Aim is to minimize number of beams in reactor chamber

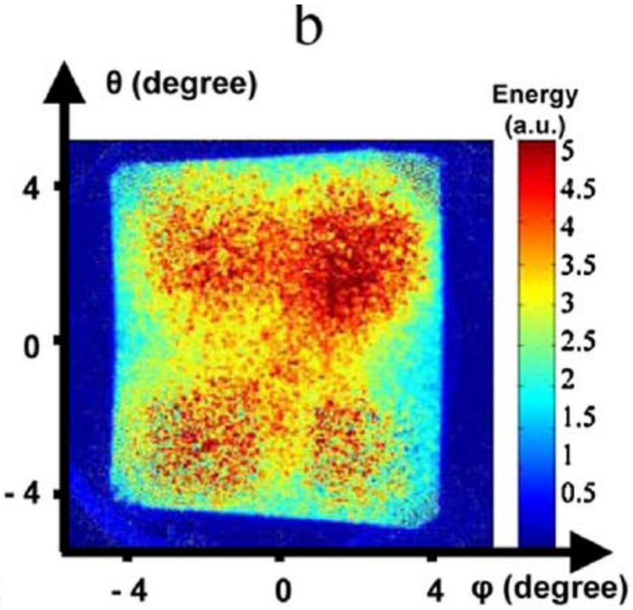
Laser absorption in foam is high even for large incidence angles

Efficient smoothing in foam layer

PALS studies initiated LIL and Gekko experiments







- Experiments at LIL laser (2.7 ns, 12 kJ) in 2007 – 2009
  (S. Depierreux *et al*., Phys. Rev. Lett. 102 (2009), 195005)
  - Plasma-induced laser beam smoothing transmitted through underdense foam
  - Studies of supersonic ionization wave in porous media (small pores)
- Planned experiment in Osaka (P. Nicolai - 2011)
  - Foil acceleration by laser beam transmitted through underdense foam