From ASTERIX to PALS

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2. Jets by PALS 2006-2007.
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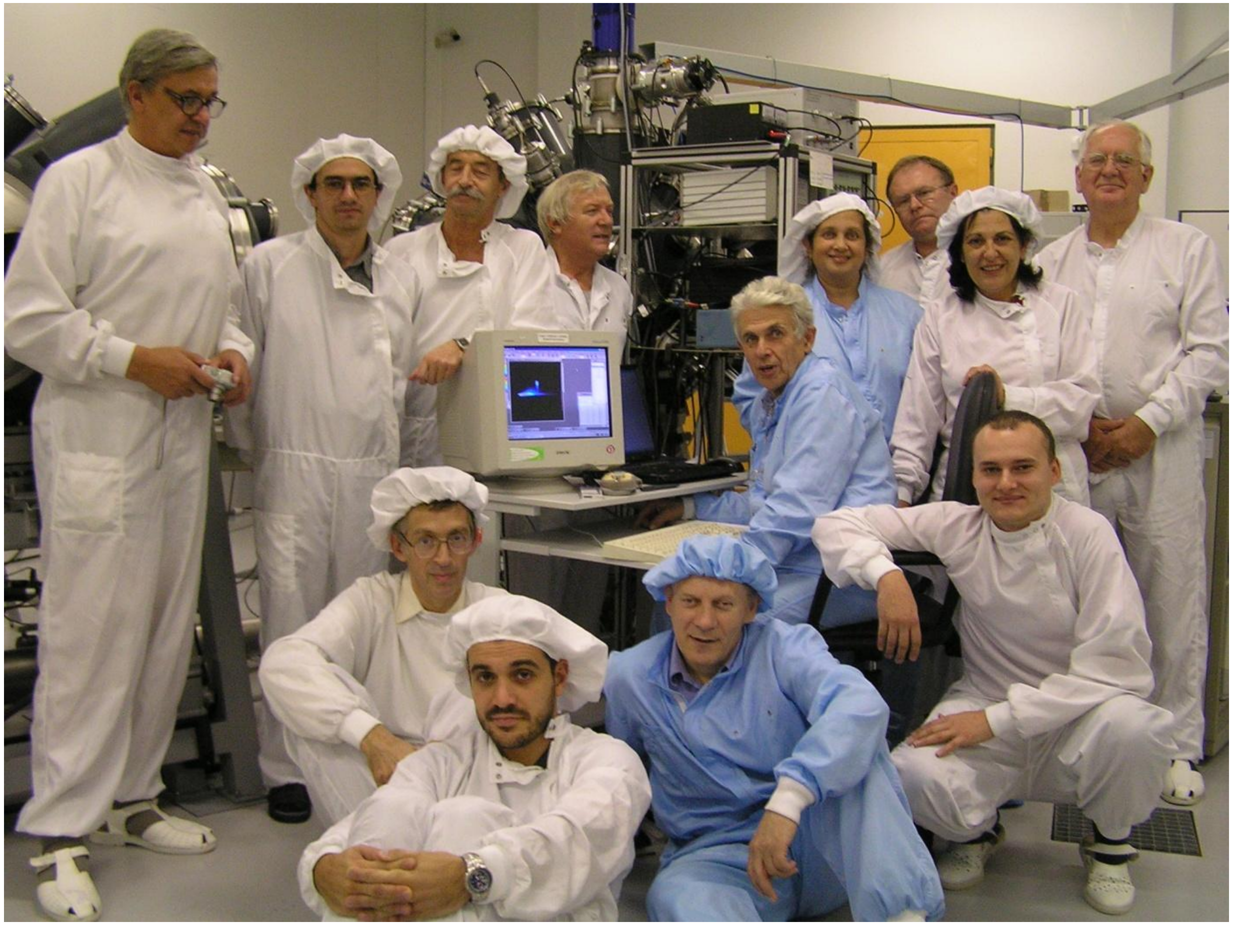
Starting in Garching

1984-1986: MPQ, Garching: ASTERIX III. laser, old IPP building
Laser energy: 100 J (1ω)
30 J (3ω)
Main topics: X-ray shadowgraphy of Hohlraums

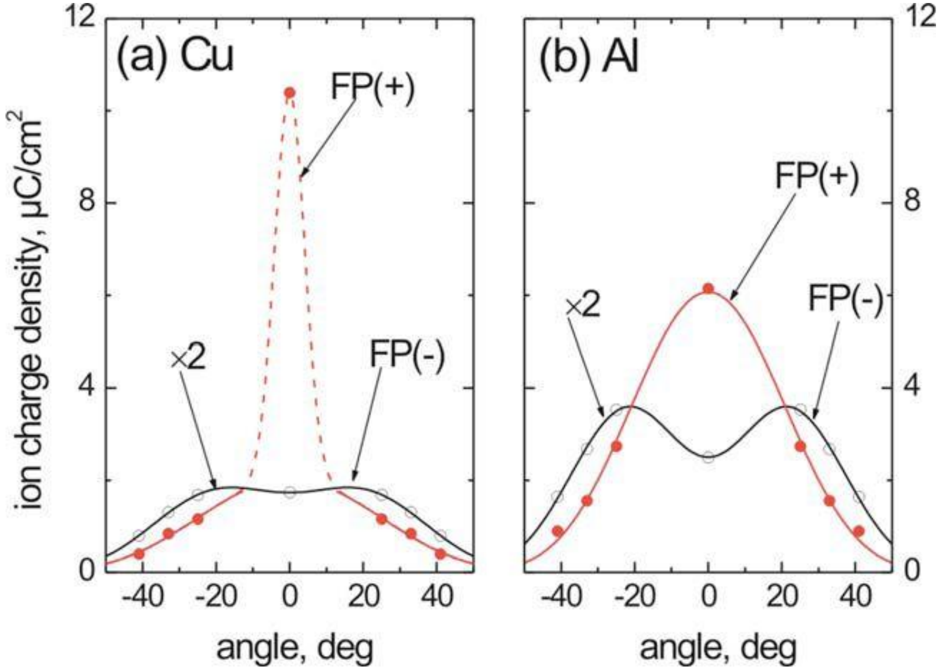
Oh, this is already the farewell party.

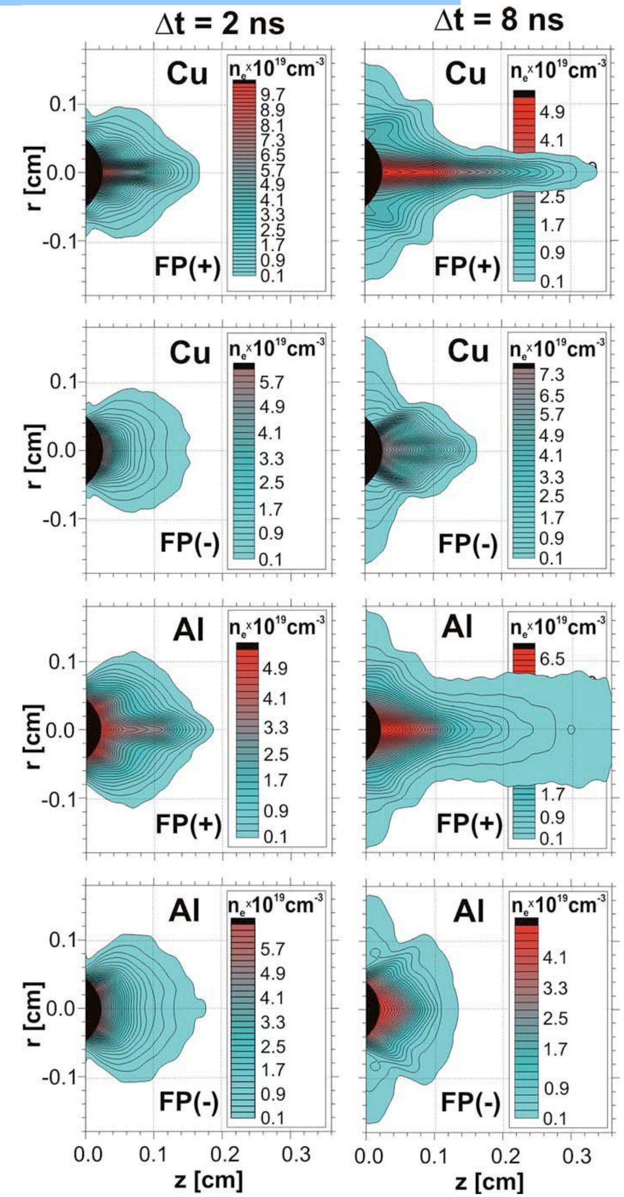
PALS Experiment with Jan Badziak

2006, Prague
Spectroscopy / production of heavy ion jets



Collimated ion jets





Collimated jets were observed for Cu/Ta both by ion collectors and by interferometry.

Laser: 69J / 3ω, 500μm spot.

Velocity: (0.2-2)×10^8 cm/s.

(Badziak et al., Appl. Phys. Lett. **91**, 081502 (2007))

Interpretation and questions

Intense heavy ion beam: A highly collimated ($\Theta<10°$), energetic (0.1–1 MeV) heavy ion jet of j>1 A/cm^2 and I>100 A at 1 m from the target can be generated with a high energy conversion efficiency approaching 10%.

Explanation of the paper: Jets are formed only for heavy ions (not for Al, CH), it is probably caused by radiative cooling.

Astrophysical relevance.

First question: Why wasn’t it seen by early ASTERIX experiments?

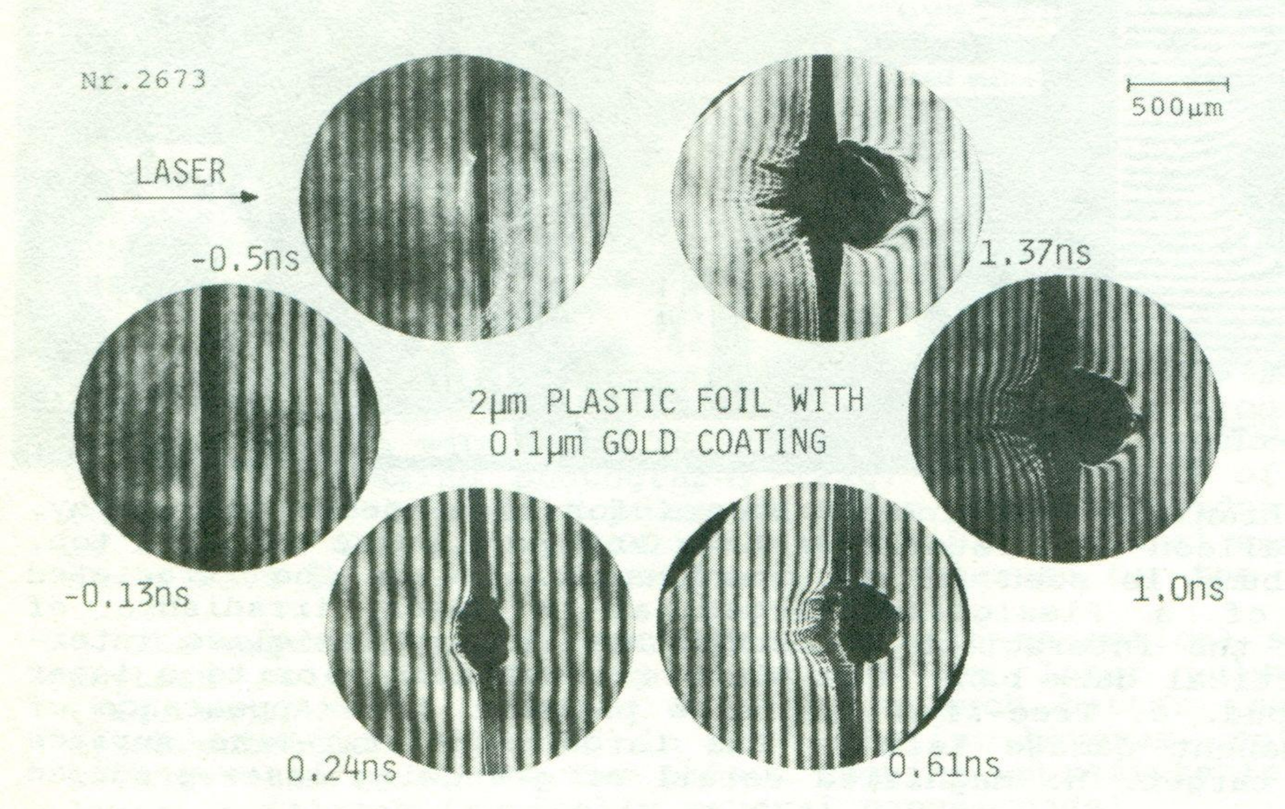
Interpretion discussed.

Other effects: Ponderomotive force, non-Gaussian beam ?? Hydrodynamics?

How to confirm radiative cooling? How to make clean conditions?

First step: Excluding effects of beam annularity.

Early filaments



R.Sigel, A.G.M. Maaswinkel, G.D.Tsakiris; Proc. SPIE **491**, 814 (1984)

Multiframe interferometry of Richard Sigel showed filaments on the front side for high-Z coated plastics targets heated by ASTERIX III. The main interest that time was the rear side, i.e. the shock waves. Filaments were attributed to self-focusing and laser beam filamentation.

λ=0.438nm, I=3×10^{13}W/cm^2, diam=400μm.

Hemisphere experiments

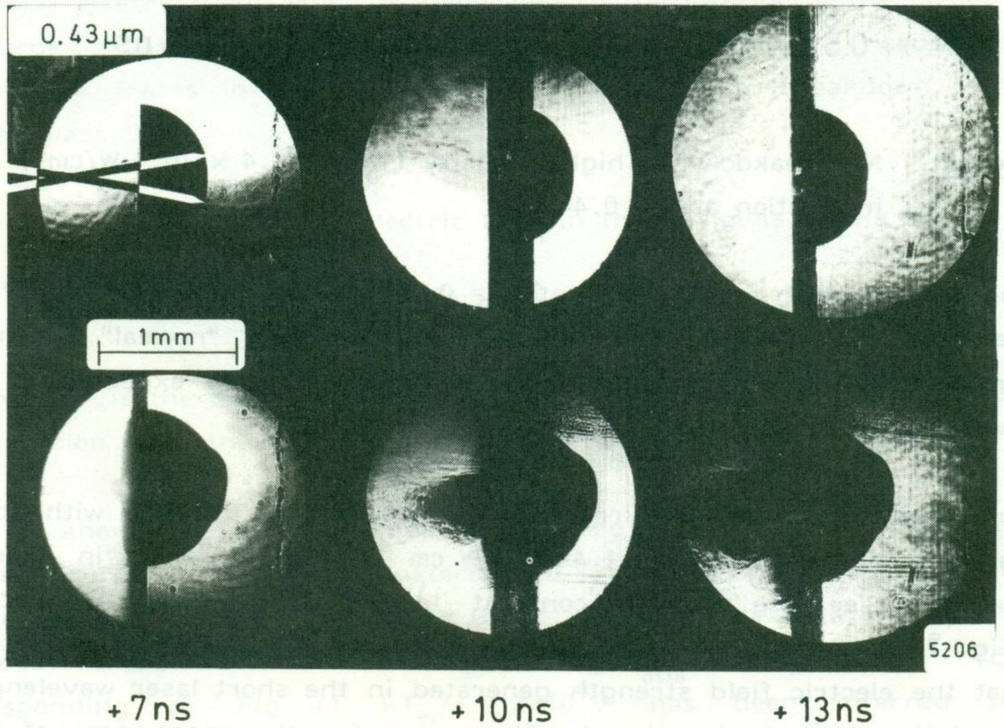
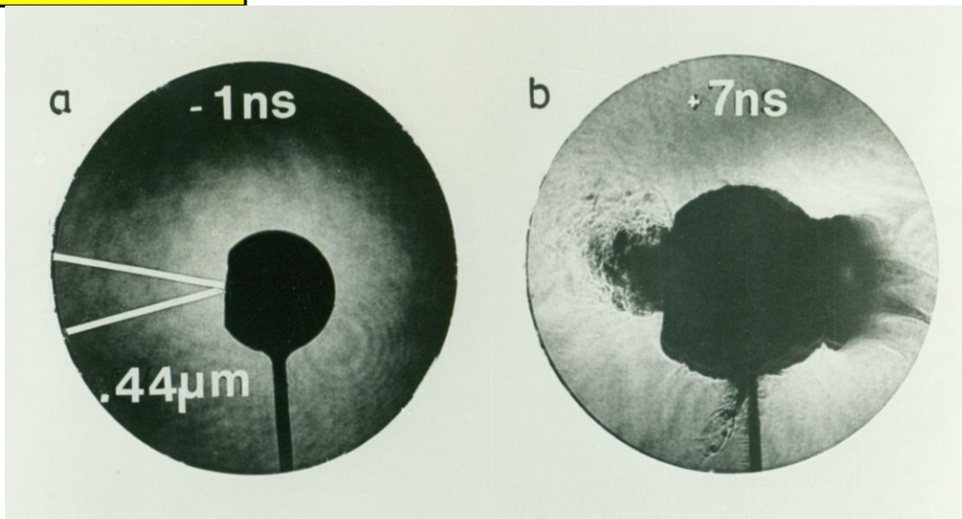


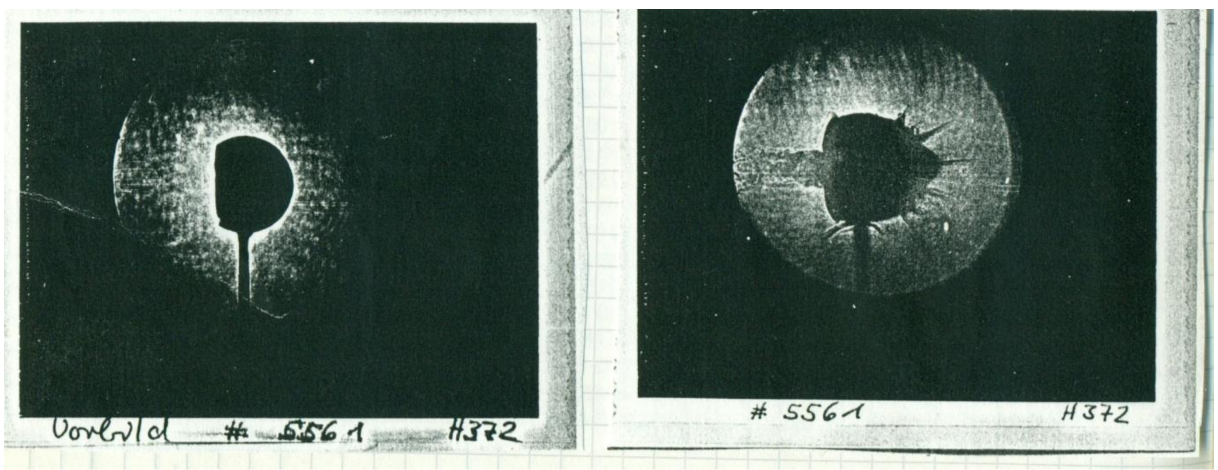
Fig. 9: Plasma jet formation at $\lambda = 0.44$ µm, $I_{abs} = 3.8 \times 10^{13}$ W/cm^2 irradiation.

Chen Shi-Sheng observed jets from hemispheres with $v=10^7$cm/s (MPQ 115, 1986). „We have not investigated the phenomenon in detail but it appears of interest as a possibility for energy concentration.”

Hohlraum experiments

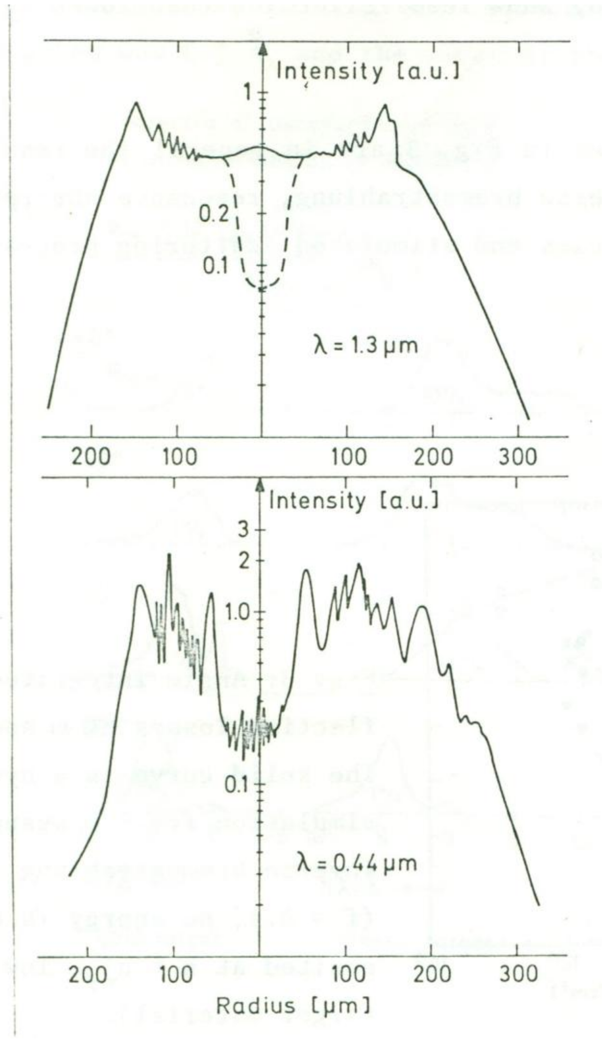


Chen Shi-Sheng's results from
I.B. Földes et al., Laser Part. Beams
6, 123 (1988)



In this unpublished photo a real collimated high-speed jet was observed. Due to the target geometry the interpretation is very difficult.

The beam profile of ASTERIX III



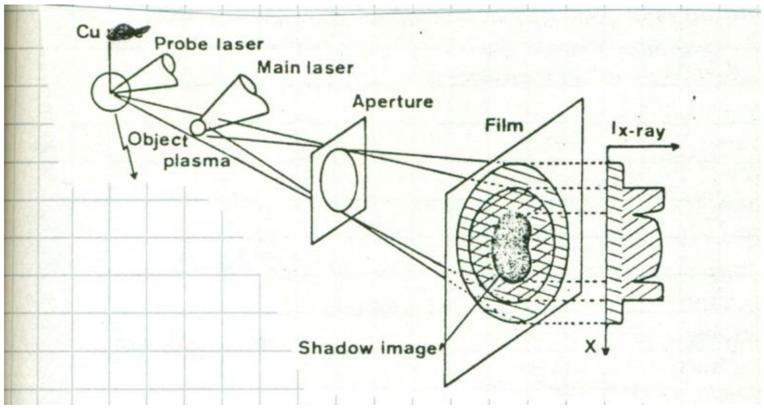
The profile of the iodine laser is annular.
It is only partly because of the beam stop at the axis of the beam (prevents reflection).
Spatial intensity distribution on target
(1mm out of focus f/2 lens).
K. Eidmann et al., 1983 Spring College on Radiation in Plasmas, Trieste, Phys. Rev. E **30**, 2568 (1984) .

It was bad for pinhole imaging x-ray shadowgraphy, which requires large spot with homogeneous illumination.
K. Koyama tried it hard, but the quality was not good.

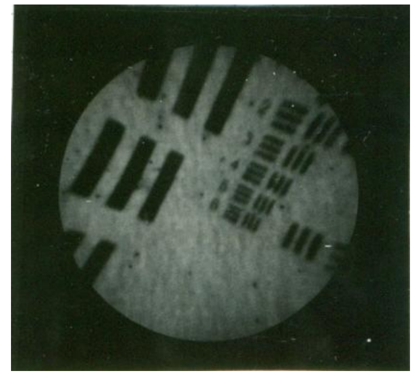
We could not make a good beam smoothing that time, therefore the point-projection method was applied.

Point-projection radiography

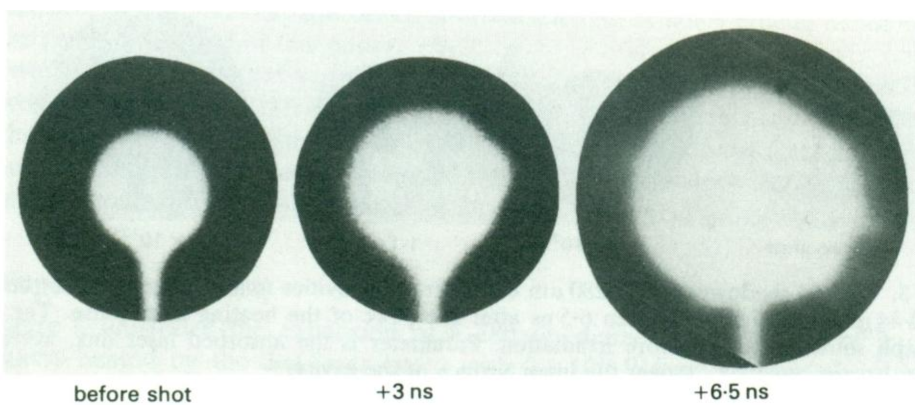
Point projection x-ray shadowgraphy was a solution for well-resolved x-ray imaging (10μm). F/1 focusing provided the small focal spot and the high resolution.



Miyanaga et al., 1983

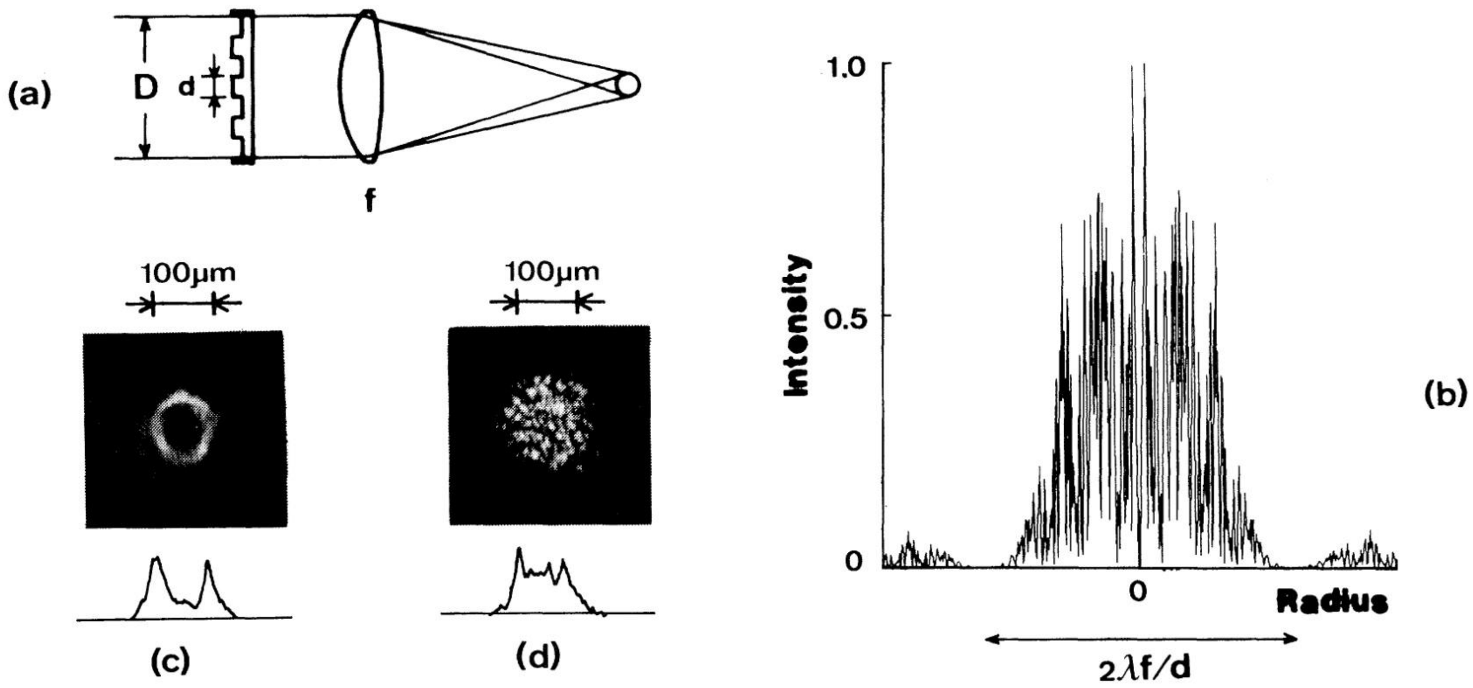


The mask shows the resolution.



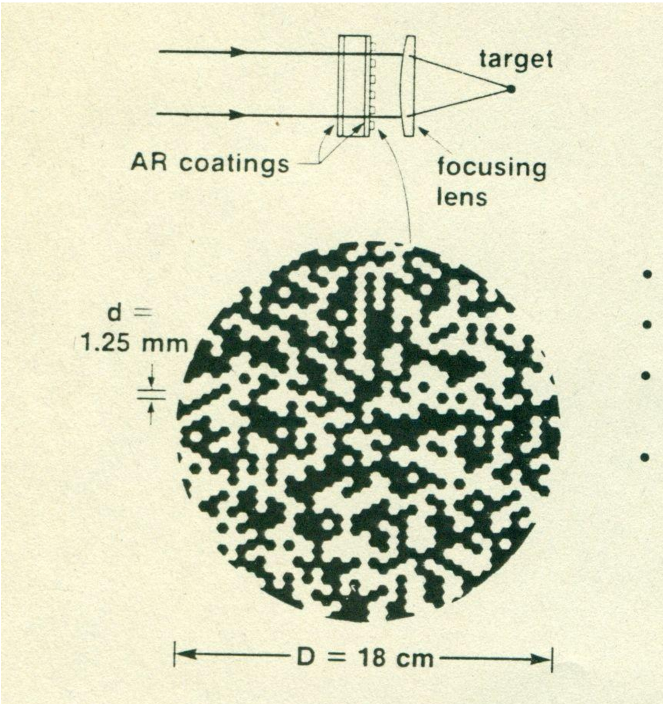
Good contrast even for Hohlraums. (Földes et al., 1988)

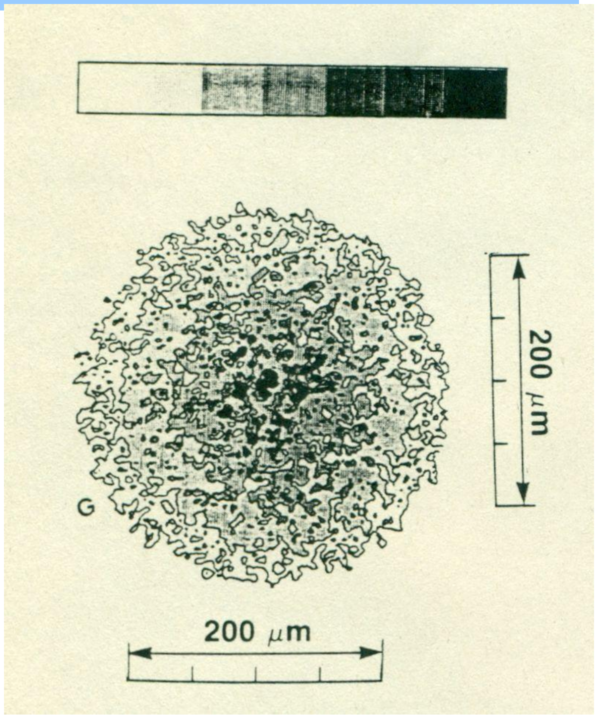
Beam smoothing by RPP



Beam smoothing by **random phase plates** was suggested by Burckhardt (Appl. Opt. **9**, 695 (1970).
Used for laser plasmas by Y. Kato et al., PRL 53, 1057 (1984).

RPP with the Omega laser





15000 hexagonal elements,
λ/100 optical path difference
(measured for 351nm).

On target intensity distribution.

Principles of RPP

$$A(\xi,\eta)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}a(x_1,y_1)\exp(2\pi i\xi x_1)\exp(2\pi i\eta y_1)dx_1dy_1$$

Fourier transform by a lens with $a(x_1,y_1)$ light amplitude at lens, ξ, η are spatial frequency at the focal plane with $\xi=x_2/\lambda f$, $\eta=y_2/\lambda f$ with λ wavelength, f focal distance.
The intensity is

$$I(\xi,\eta)=A(\xi,\eta)A^*(\xi,\eta).$$

This is the autocorrelation $r(x_1,y_1)$ of the light amplitude at the lens in the spatial domain:

$$r(x_1,y_1)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}a^*(u,v)a(u+x_1,v+y_1)dudv.$$

In case of a random phase mask of sizes d with π phase shift the autocorrelation is 0 for

$$\left(x_1^2+y_1^2\right)^{1/2}>d,$$

for $\left(x_1^2+y_1^2\right)^{1/2}\le d$ contributions from all areas will add up as a Fourier transformation of a step function.

The result of a Fourier transformation for a step function in 1dimension:

$$F(y) = \frac{d}{4} \sin c\left(\frac{d\pi y}{\lambda f}\right)$$

With the zero at $y_0 = \lambda f/d$, more accurately an Airy-pattern for circular apertures.

Example: spot size for PALS.
$f=60cm$, $\lambda=0.44\mu m$ in case we want $y=500\ \mu m$, then **a mask of size d~$500\ \mu m$ needed**.

This size could have been made that time already. Why wasn't it?
Innaccurate phase shift of the phase mask:

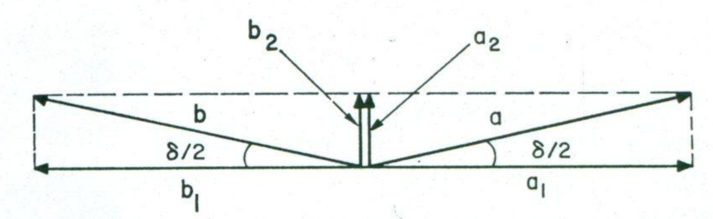


Fig. 6. Decomposition of phasors with an inaccurate phase shift.

If the difference between the phasors a and b is not equal to π , but $|a|=|b|$, they can be decomposed with the δ deviation:

$$|a_1| = |b_1| = |a| \cos\left(\delta/2\right),$$

$$|a_2| = |b_2| = |a| \sin\left(\delta/2\right).$$

In case of a perfect π phase difference one has the contribution from a_1 and b_1, i.e. from the cosine term only.
The sine term, a_2 and b_2 gives no phase shiftit is added in the focal plane, which gives a narrow peak (focus) as without the RPP.
The spike intensity:

$$P_2 = P \sin^2\left(\delta/2\right),$$

therefore the ratio of noise/signal is:

$$R = N \frac{\sin^2\left(\delta/2\right)}{\cos^2\left(\delta/2\right)} = N \tan^2\left(\delta/2\right) \approx N \frac{\delta^2}{4}.$$

The higher the number of phasors, the higher accuracy needed, e.g. for $N=10^4$ the required accuracy is better than $1°$.
In 1985 we could not make it. Now it must be possible.
Let's try it with PALS!

JET observation at PALS seems to be really new. Random phase plates can be tried to see whether the annular beam distribution is relevant.

Thank you for your attention!