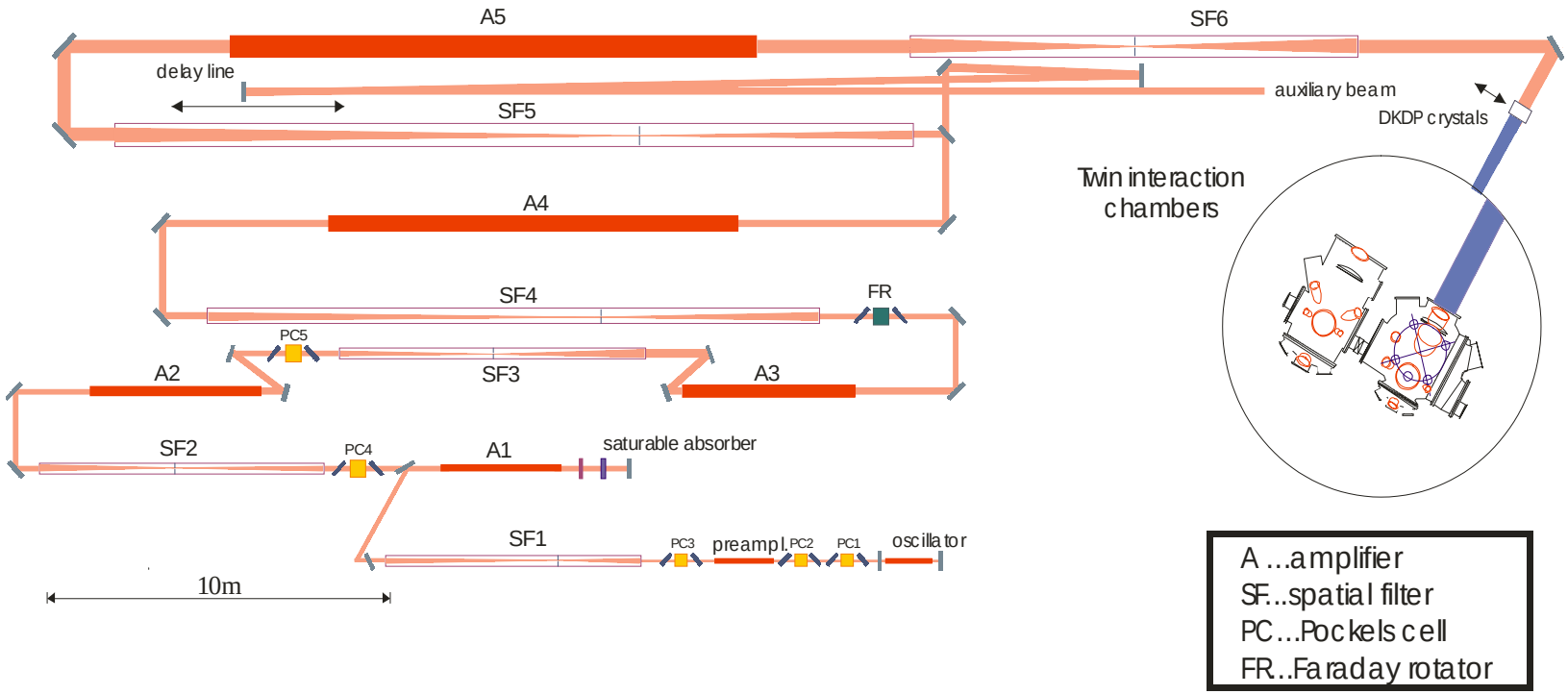
Review of PALS Facility and Experiment

K. Rohlena

Joint Research Centre PALS

Institute of Physics & Institute of Plasma Physics

Acad. Sci., Prague, Czech Republic

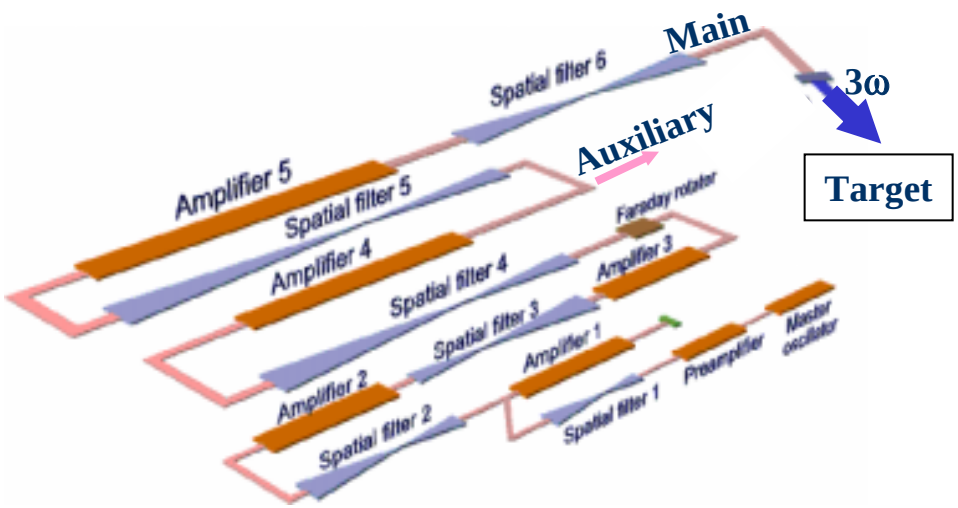


Overall scheme of the PALS system showing the interaction chambers and the conversion crystals

System seen from the oscillator table

Terawatt gaseous laser PALS at λ = 1315 nm and 438 nm (3ω)

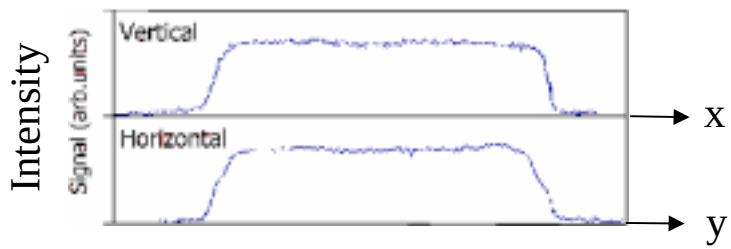
Prague **A**sterix **L**aser **S**ystem (**PALS**)



Main beam

Pulse energy	0.8 kJ
Pulse duration	0.4 ns
Power	3 TW
Target intensity	3×10^{16} W/cm^2
Beam diameter	30 cm
Beam path	180 m
Repetition	1/(25 min)
Wavelength	1315.24 nm
Gain linewidth	0.02 nm (0.1cm^{-1})

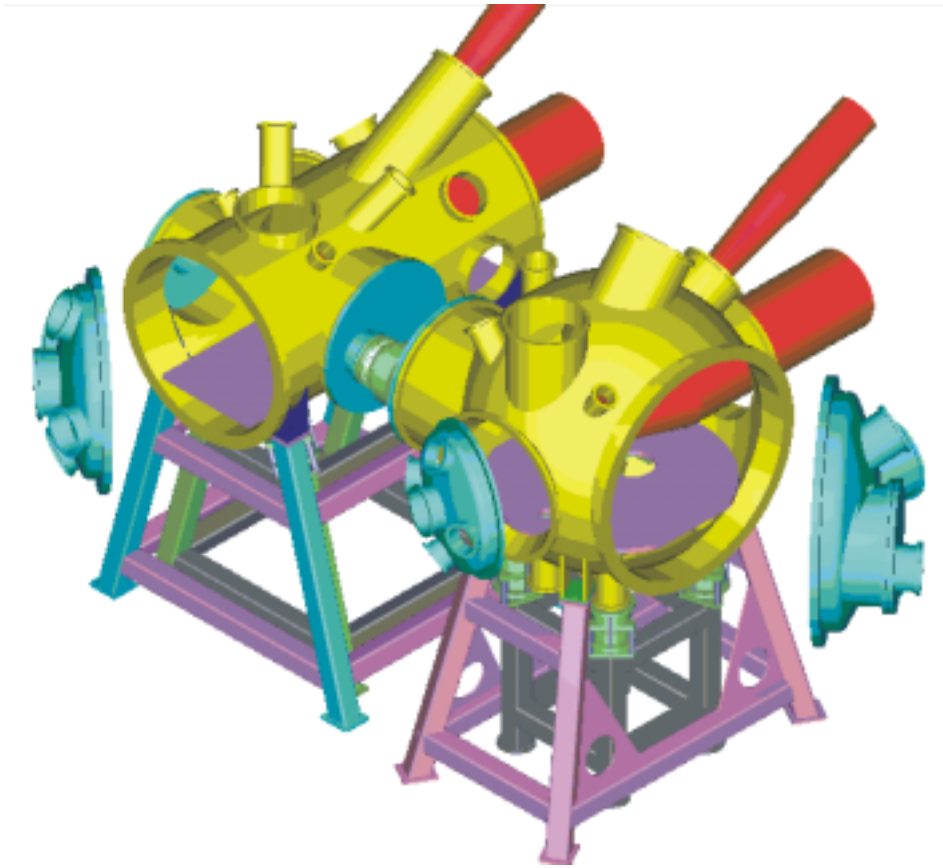
Beam profile

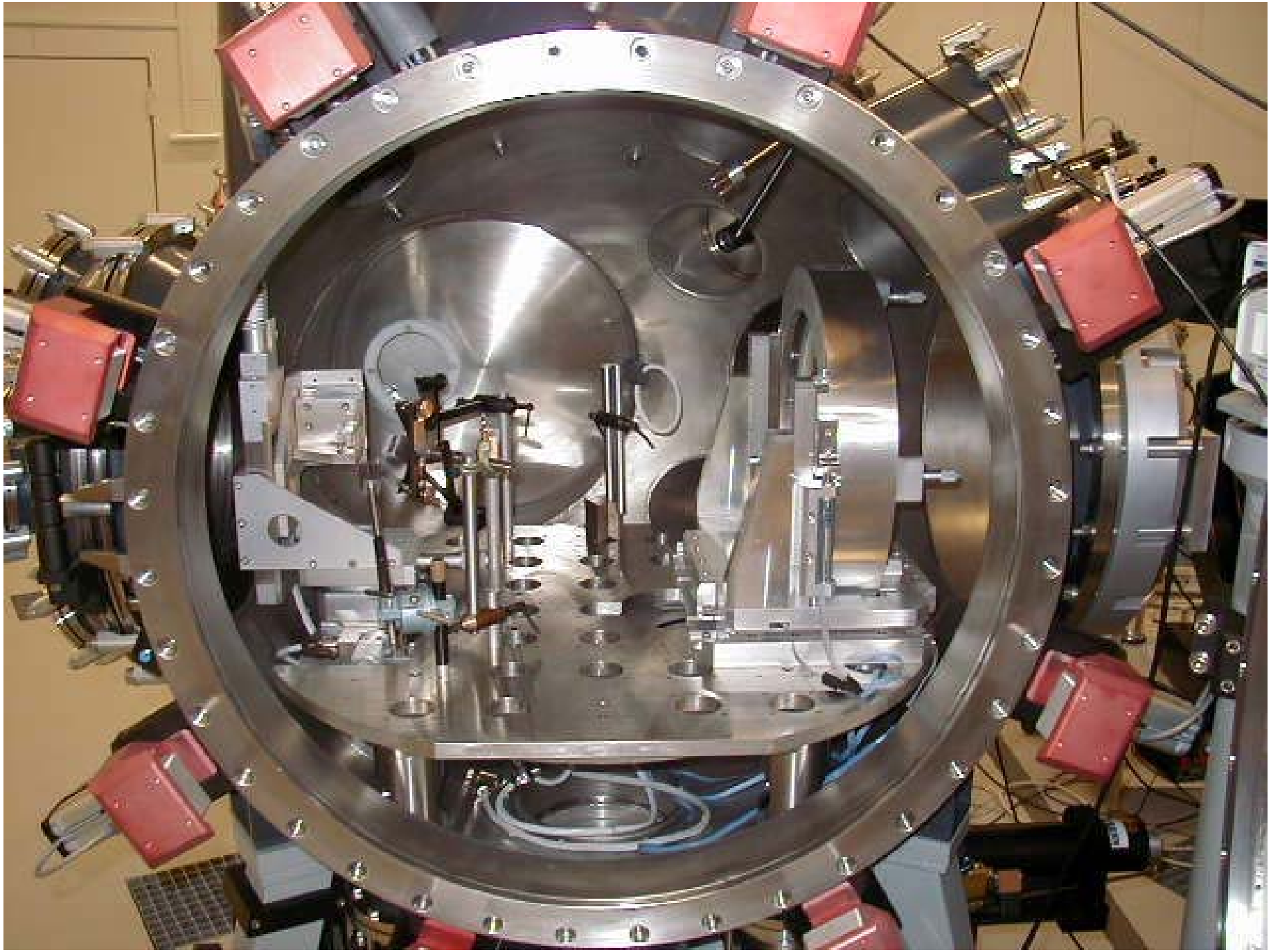


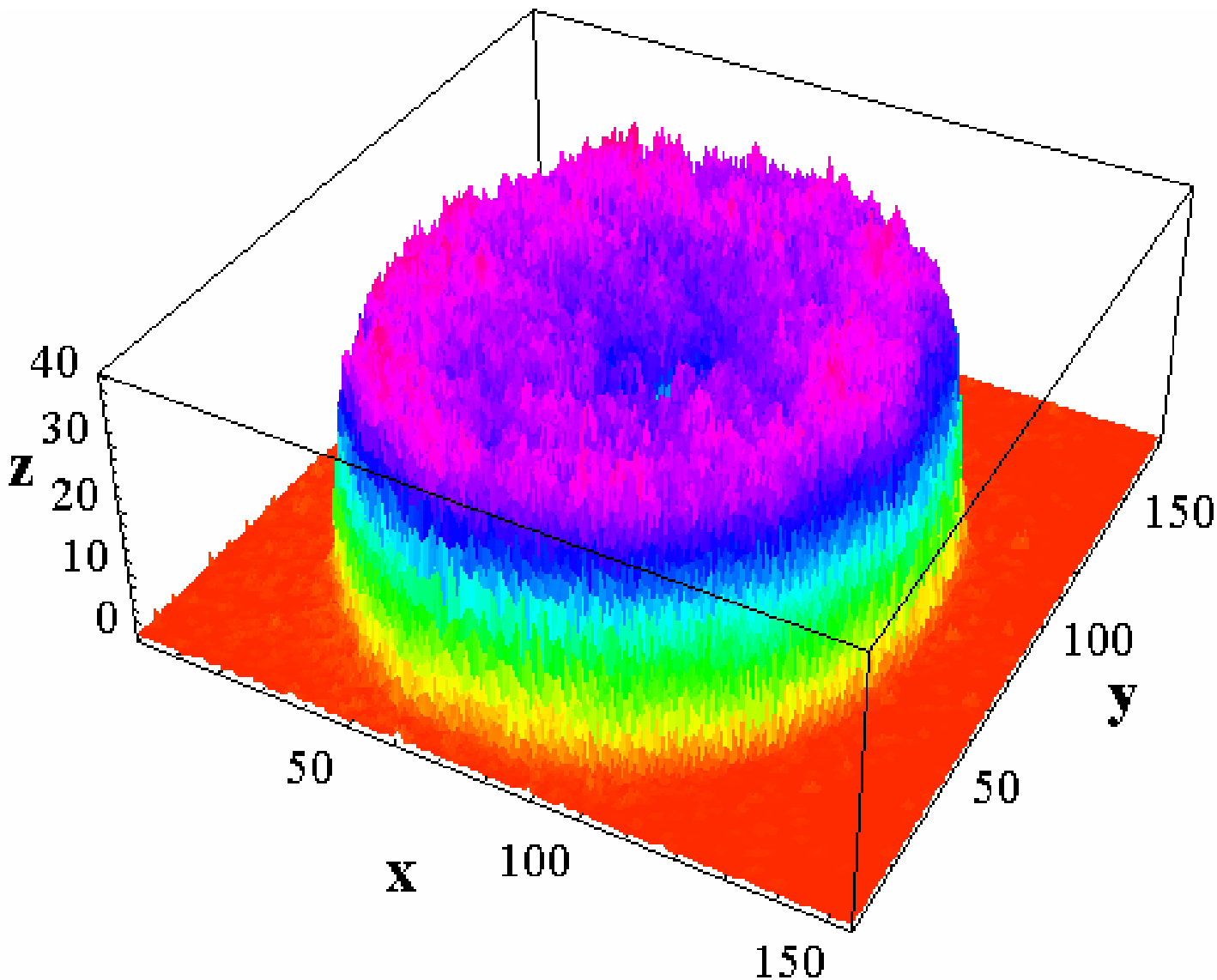
Spatial coordinates x ⊥ y

Interaction chamber

Design J.C. Lagron Univ. Paris-Sud and LULI



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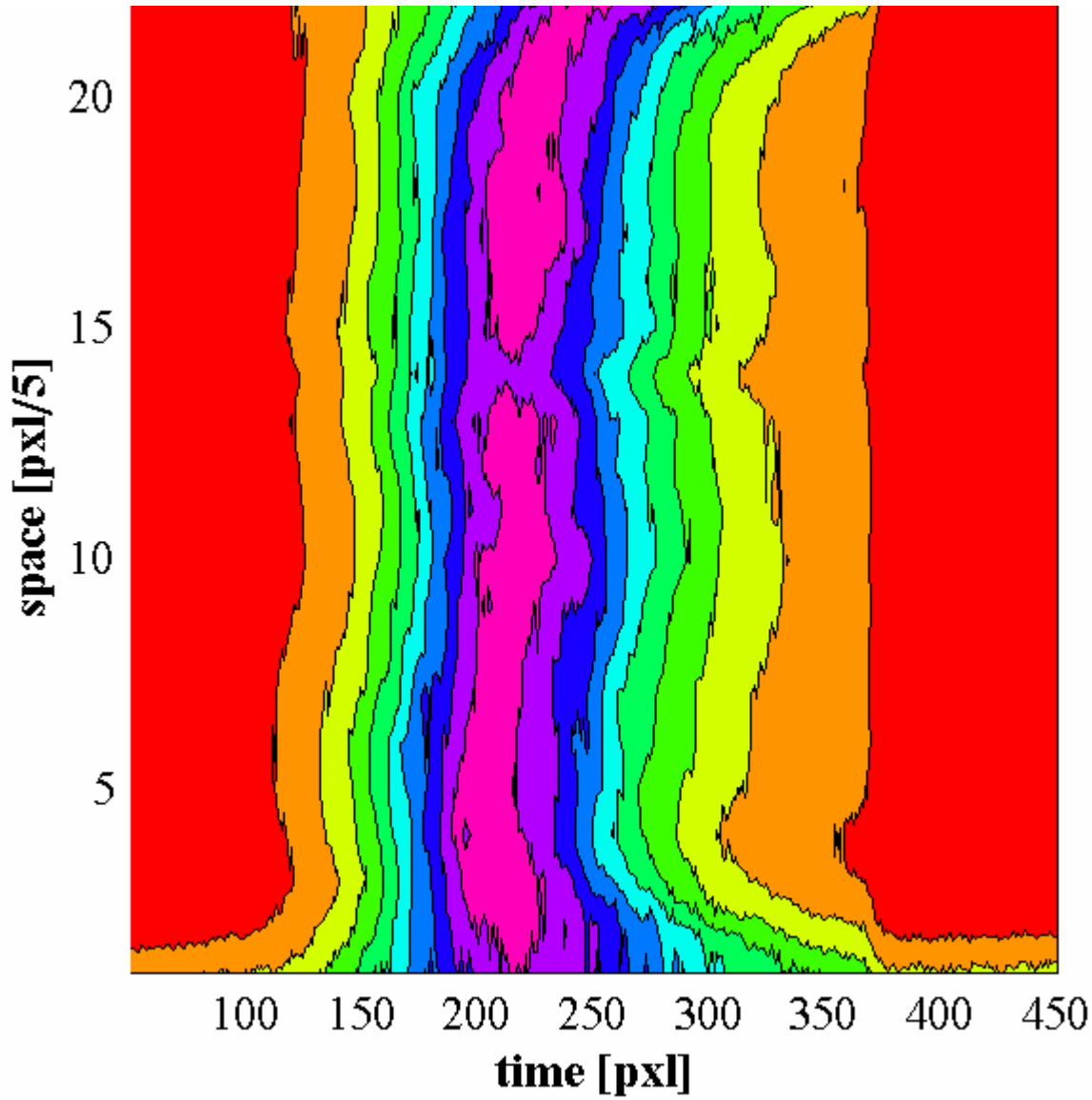
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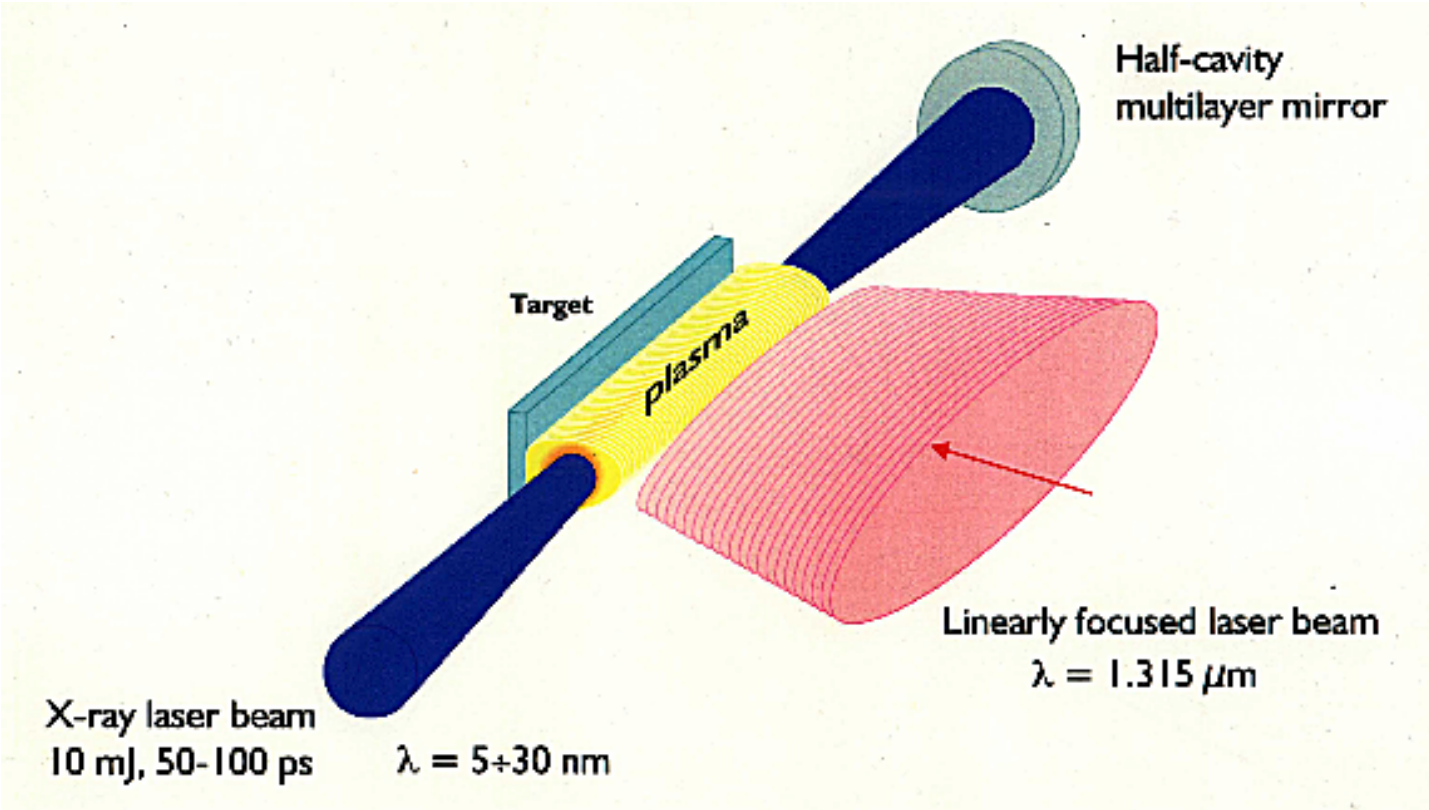
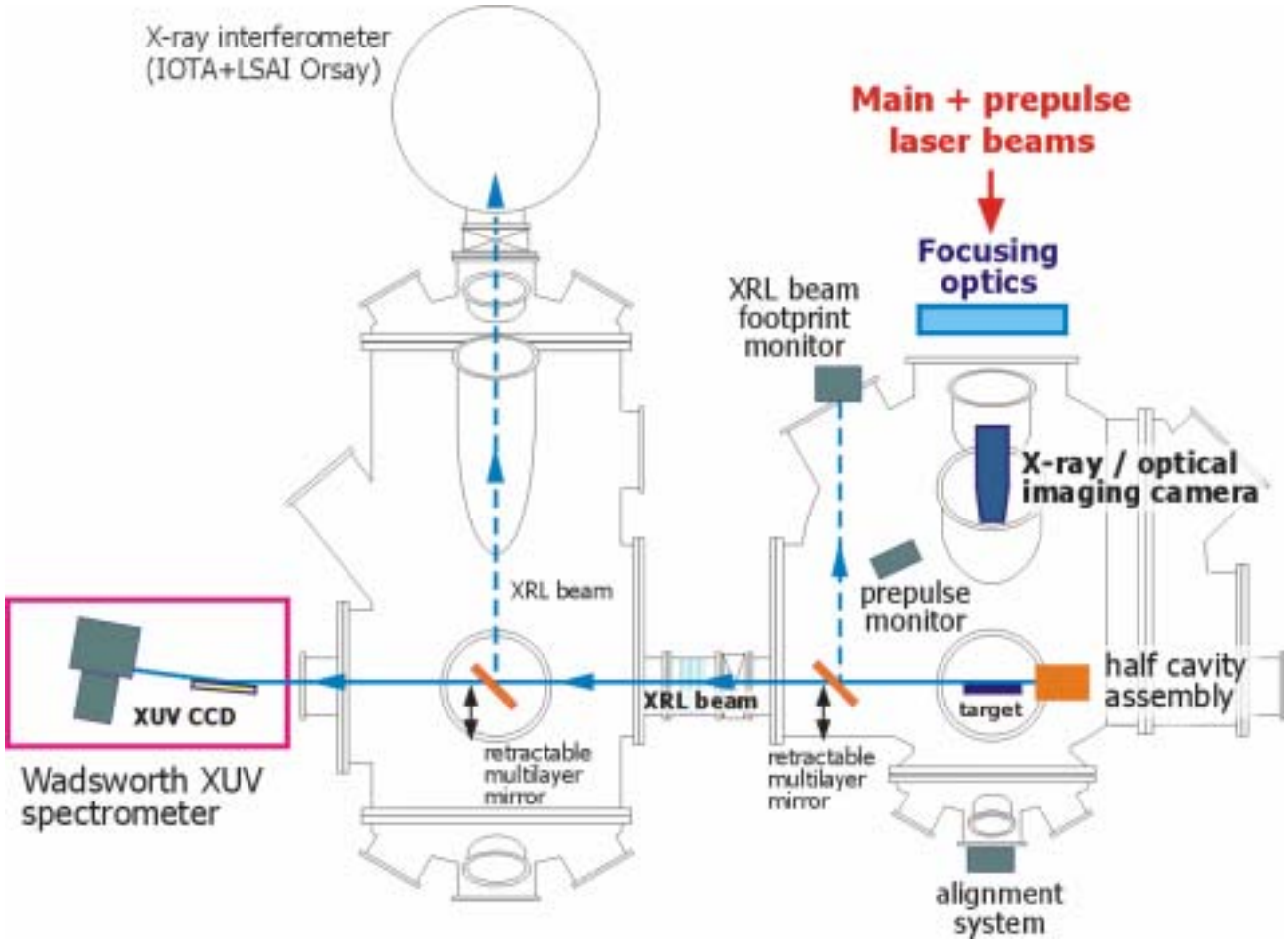

Half-cavity
multilayer mirror
Target
plasma
Linearly focused laser beam
λ = 1.315 μm
X-ray laser beam
10 mJ, 50-100 ps
λ = 5÷30 nm


X-ray interferometer
(IOTA+LSAI Orsay)
Main + prepulse
laser beams
Focusing
optics
XRL beam
footprint
monitor
X-ray / optical
imaging camera
XRL beam
prepulse
monitor
half cavity
assembly
XUV CCD
XRL beam
target
retractable
multilayer
mirror
retractable
multilayer
mirror
Wadsworth XUV
spectrometer
alignment
system

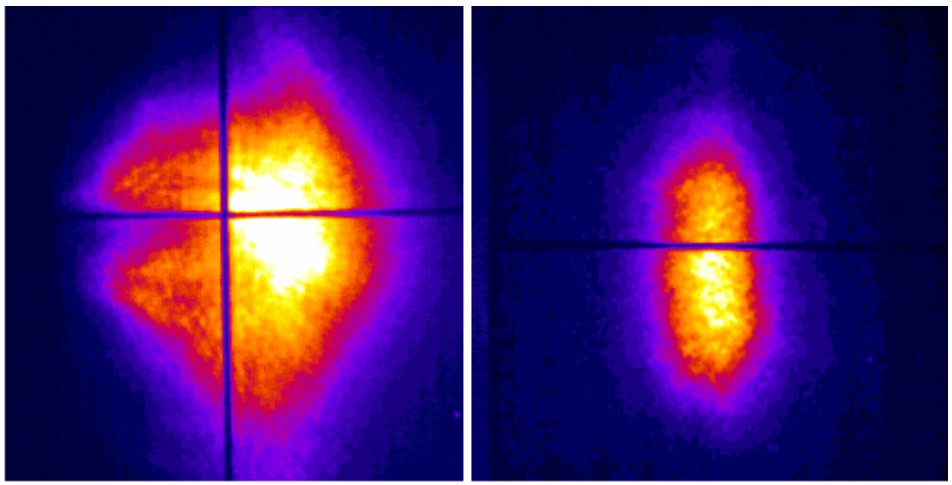
PALS XUV laser parameters

Wavelength **21.22 nm**
Pulse duration **80 -100 ps**

Results of optimization in 2002 by varying the delay between the main and the auxiliary driving pulses:

Beam energy **4 - 10 mJ**
Peak power **40 - 150 MW**

Footprints of the Zn laser beam



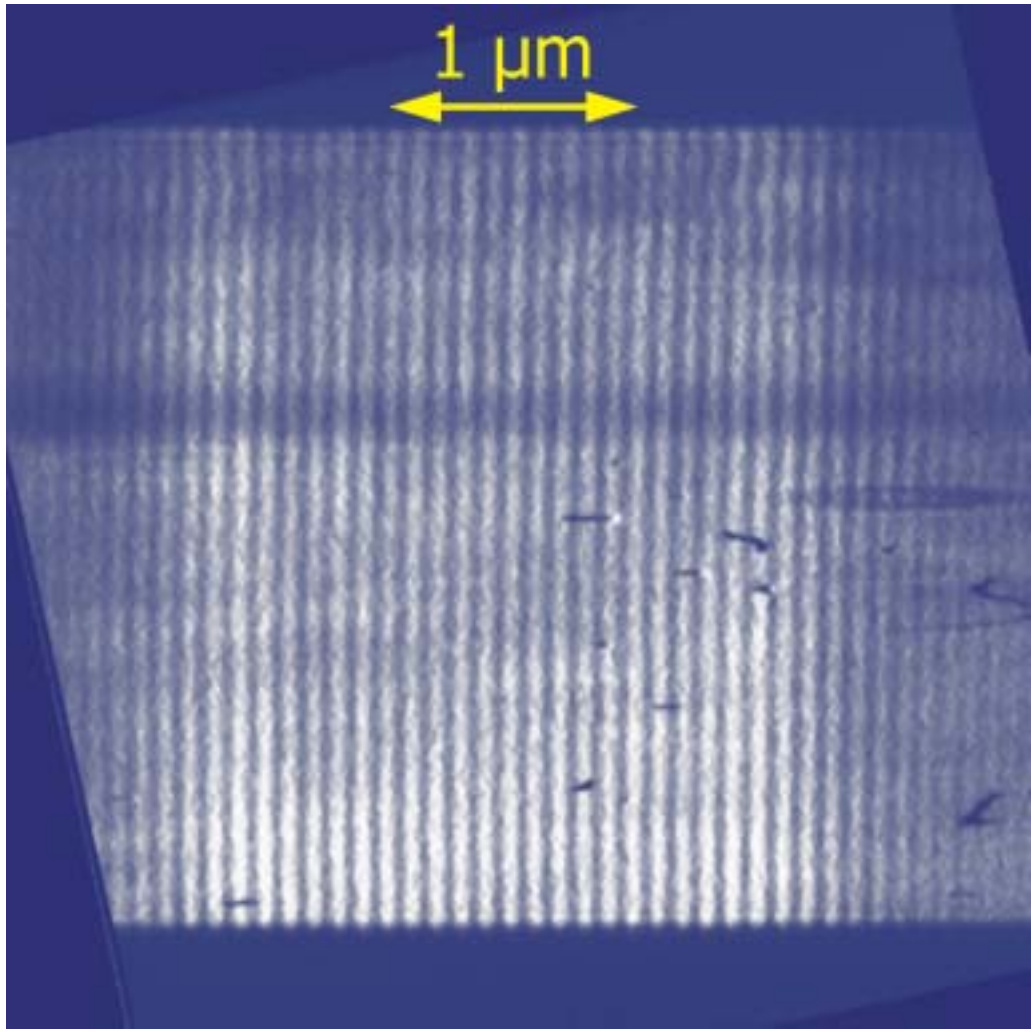
div. 3.5x5.5 mrad
Δt = 10 ns
(2001)

div. 1x4 mrad
Δt = 50 ns
(2002)

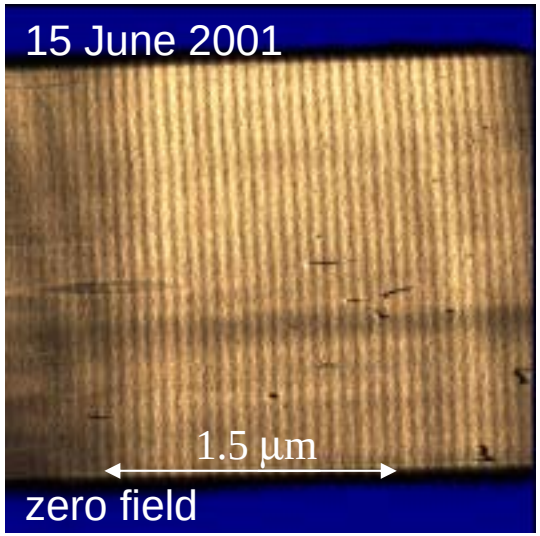
Photons per pulse:
5.10^{14} - 10^{15}

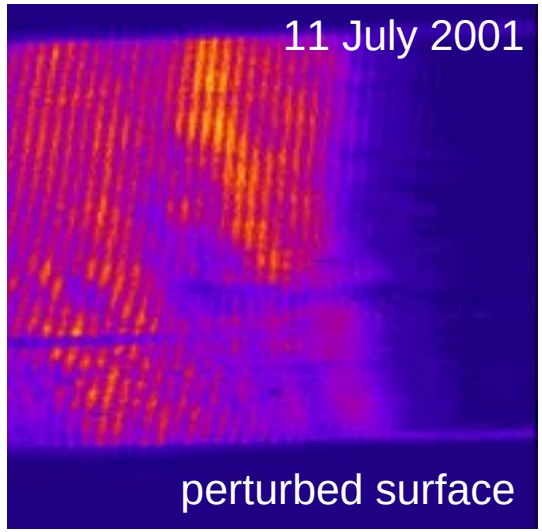
Brightness (0.001)
> 3.10^{27} phot. s^{-2} mm^{-2} $mrad^{-2}$

=> record brightness of an XUV source achieved thus far


1 μm

Nano-scale interferometry of surfaces



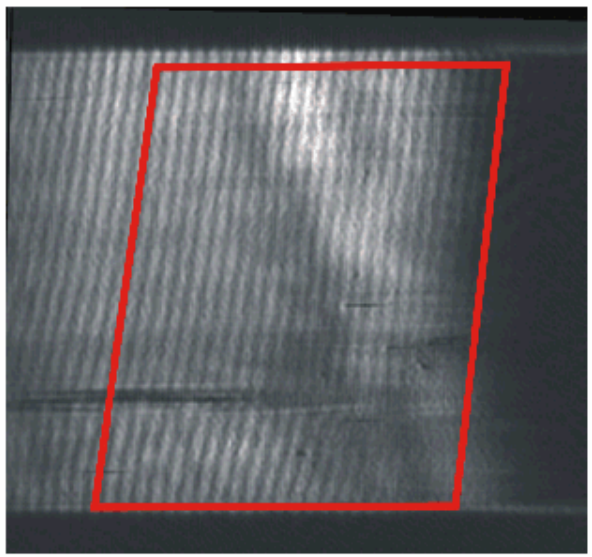


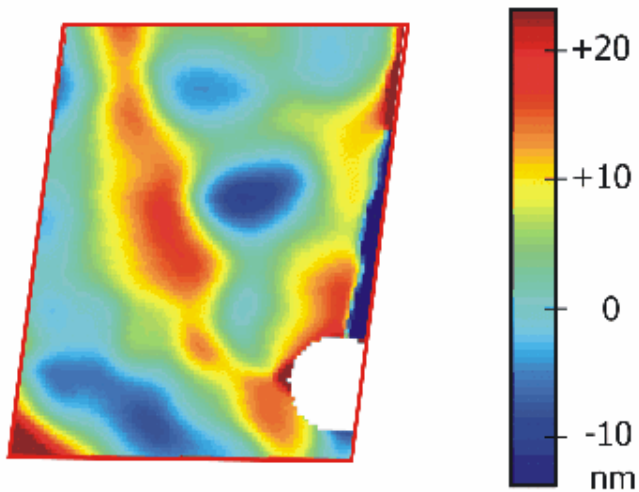
Wave-splitting grazing incidence Fresnel interferometer

Design: Laboratoire Charles Fabry (IOTA) & PALS

Studies of deformation in Nb-coated electrodes in strong electric fields.

Interferogram of the deformed surface at 50 MVm^{-1} and the corresponding surface relief map





PALS research projects from European and other institutions

Research topics

- laser and nonlinear optics
- laser produced plasma
    - highly charged ions
    - X-ray and UV plasma sources
    - X-ray spectrometry
    - applications (biophysics - X-ray contact microscopy, …)

Users (from Sept 2000)

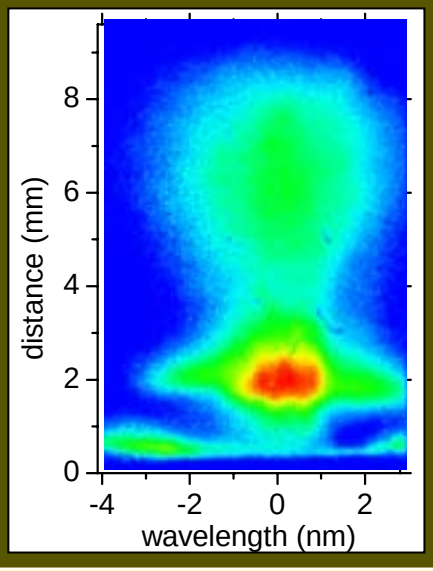
- France (LSAI Orsay, CEA Saclay)
- Germany (TU Darmstadt, FSU Jena, UT Chemnitz)
- Italy (INFN & UM Bicocca)
- Netherlands (IPP FOM Nieuwegein)
- Poland (MUT Warsaw, IPPLM Warsaw)
- USA (LLNL, Livermore)
- Czech Rep. (CTU Prague, IP Prague)

X-ray sources for X-ray microscopy

H. Fiedorowicz et al.

SOFT X-RAY SPECTRA FROM NITROGEN/HELIUM GAS PUFF TARGET IRRADIATED WITH PALS

SOFT X-RAY SPECTRUM FROM ARGON/HELIUM GAS PUFF TARGET IRRADIATED WITH PALS

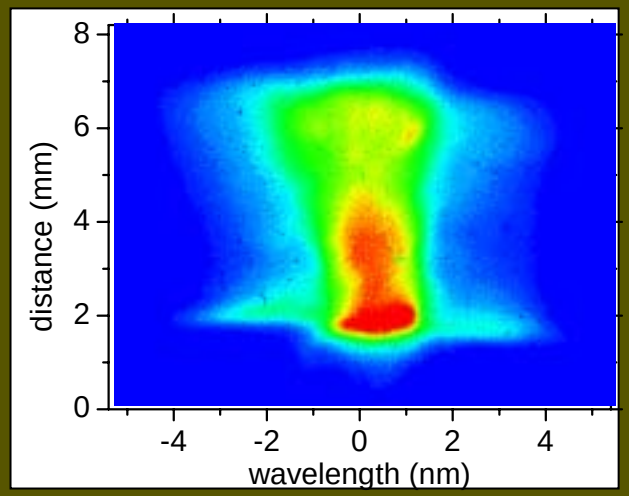


Project PALS/003

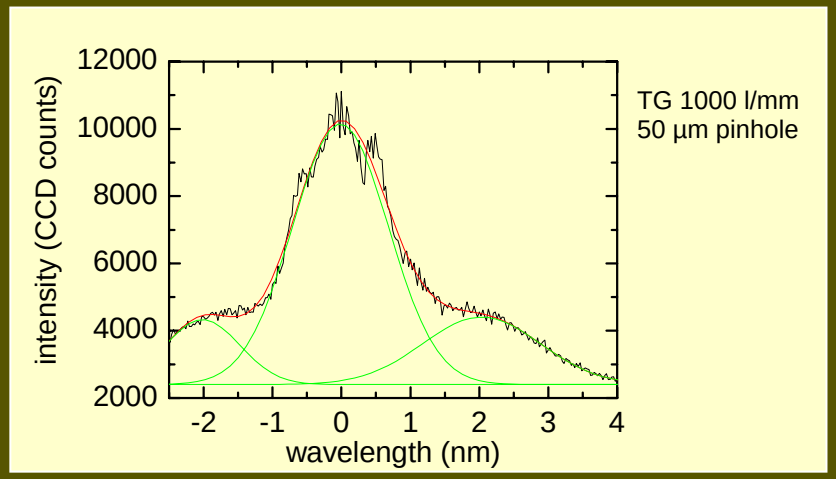
"water window"

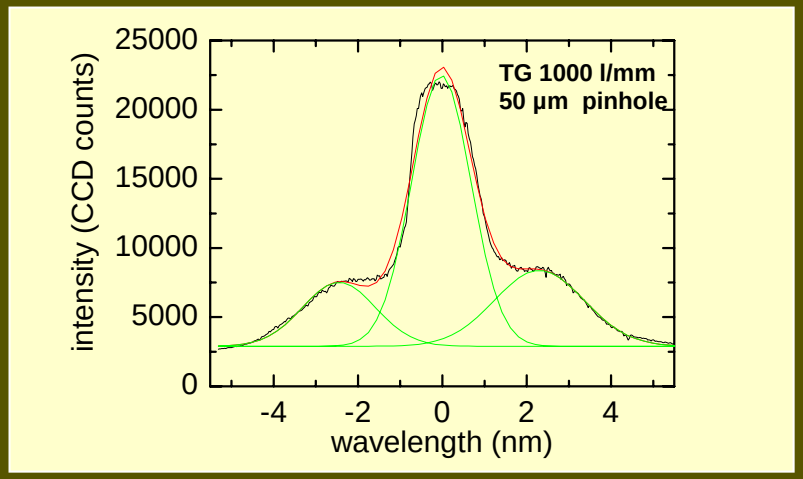
2.3-4.4 nm

LASER BEAM
628 J, 0.5 ns

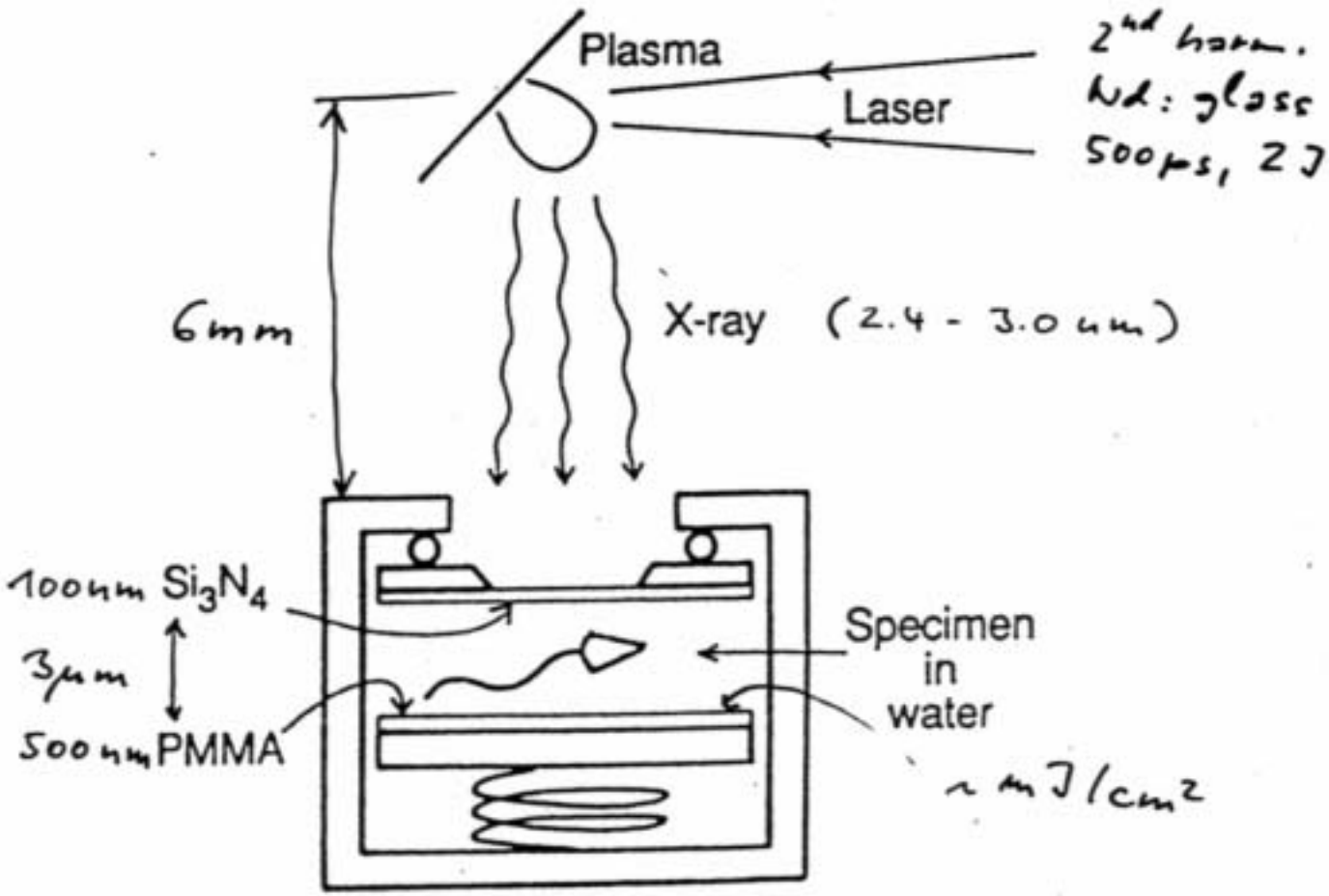


LASER BEAM
271 J, 0.5 ns



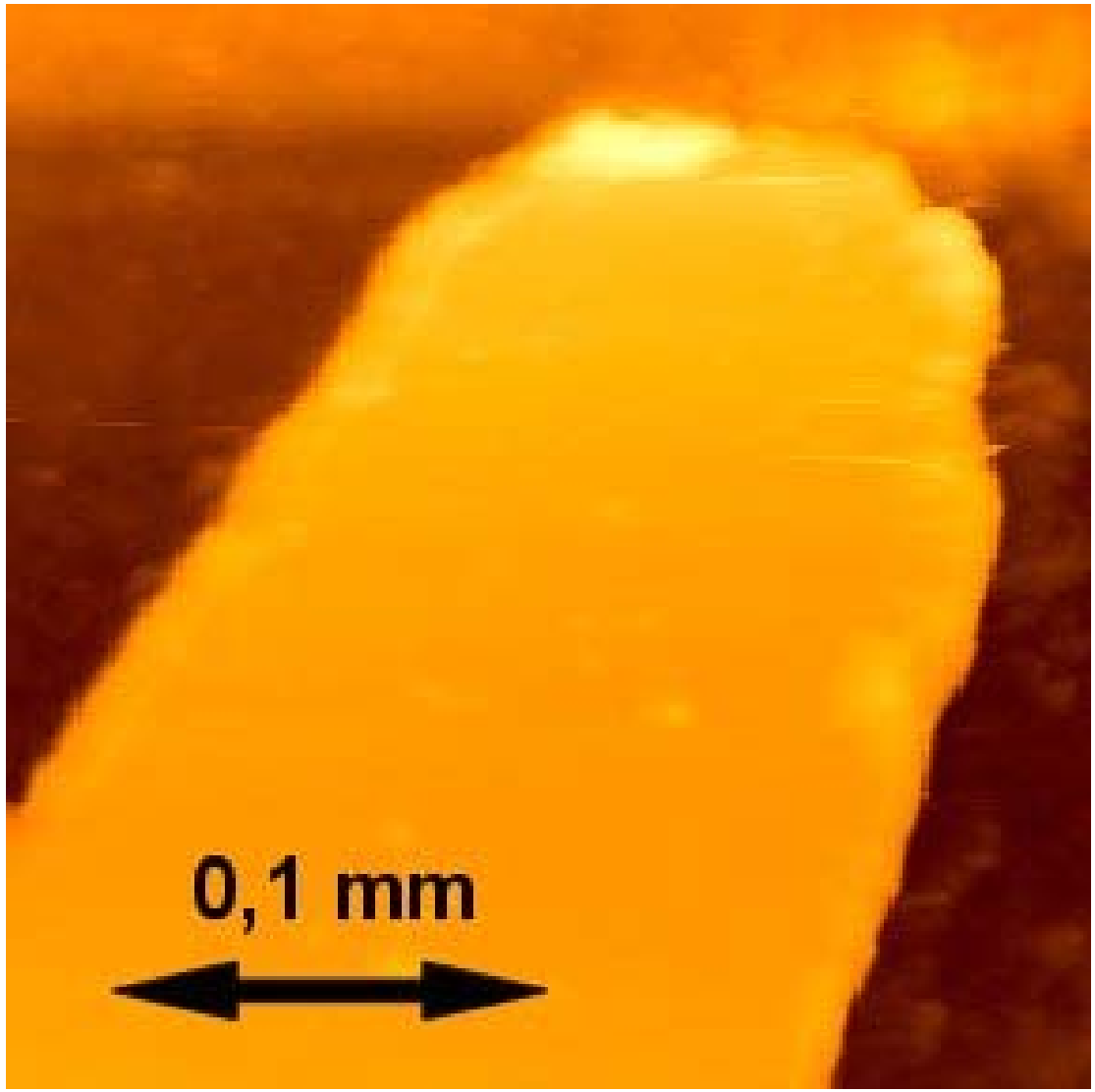


TOMIE T. et al.: Science 252, 691 (1991)



X-ray Contact microscopy: Caenorhabditis Elegans

The model organism for 2002 Nobel winner Sydney Brenner



Soft X-ray Contact Microscopy (SXCM) of living micro-organisms

G. Poletti, T. Desai, A. Bernardinello, D. Batani et al.

- **XUV irradiation of samples + XUV spectroscopy**
- **developing of imprints on PMMA resists by etching**
- **AFM scanning of the etched relief**

PALS 1ω & 3ω point focus

Au, Mo, PTFE targets

I > 10^{14} Wcm^{-2}

The first SXCM application for multicellular organisms.

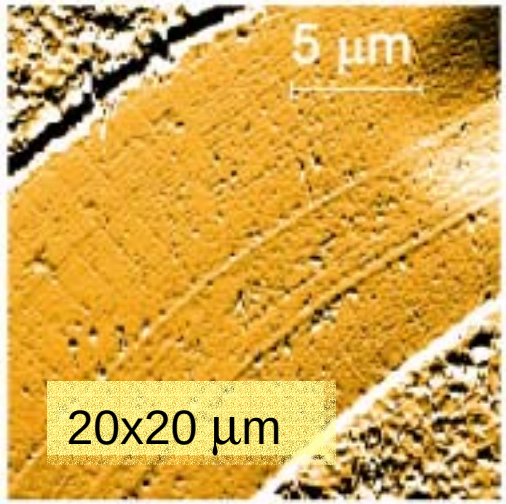
SXCM in-vivo pictures of the Nematodae worm *Caenorhabditis elegans*

Fresh SXCM results 2003 - Università di Milano-Bicocca

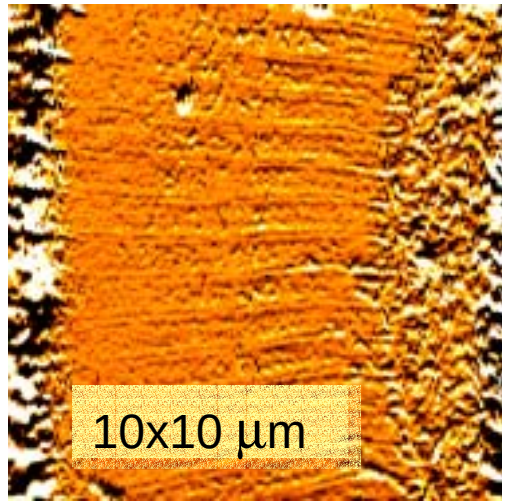
Details of C. Elegans internal structures

SPIE 48th Annual Meeting
San Diego, Proc. Vol. 5196;

Laser & Particle Beams

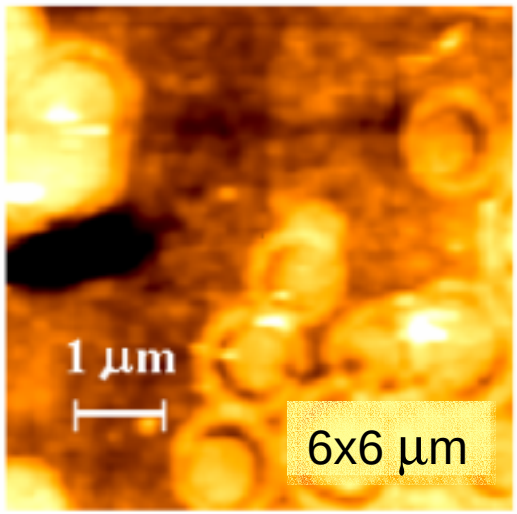


Cuticle with annuli

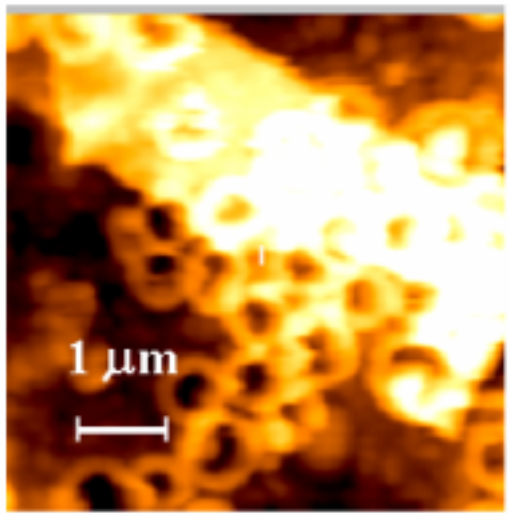


Muscle fibers

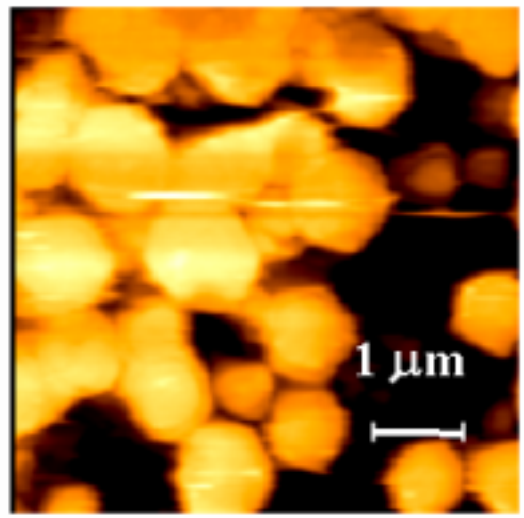
Cell nuclei:



hypodermal nuclei



neuronal nuclei



muscle nuclei

Multi-frame laser interferometry/shadowgraphy

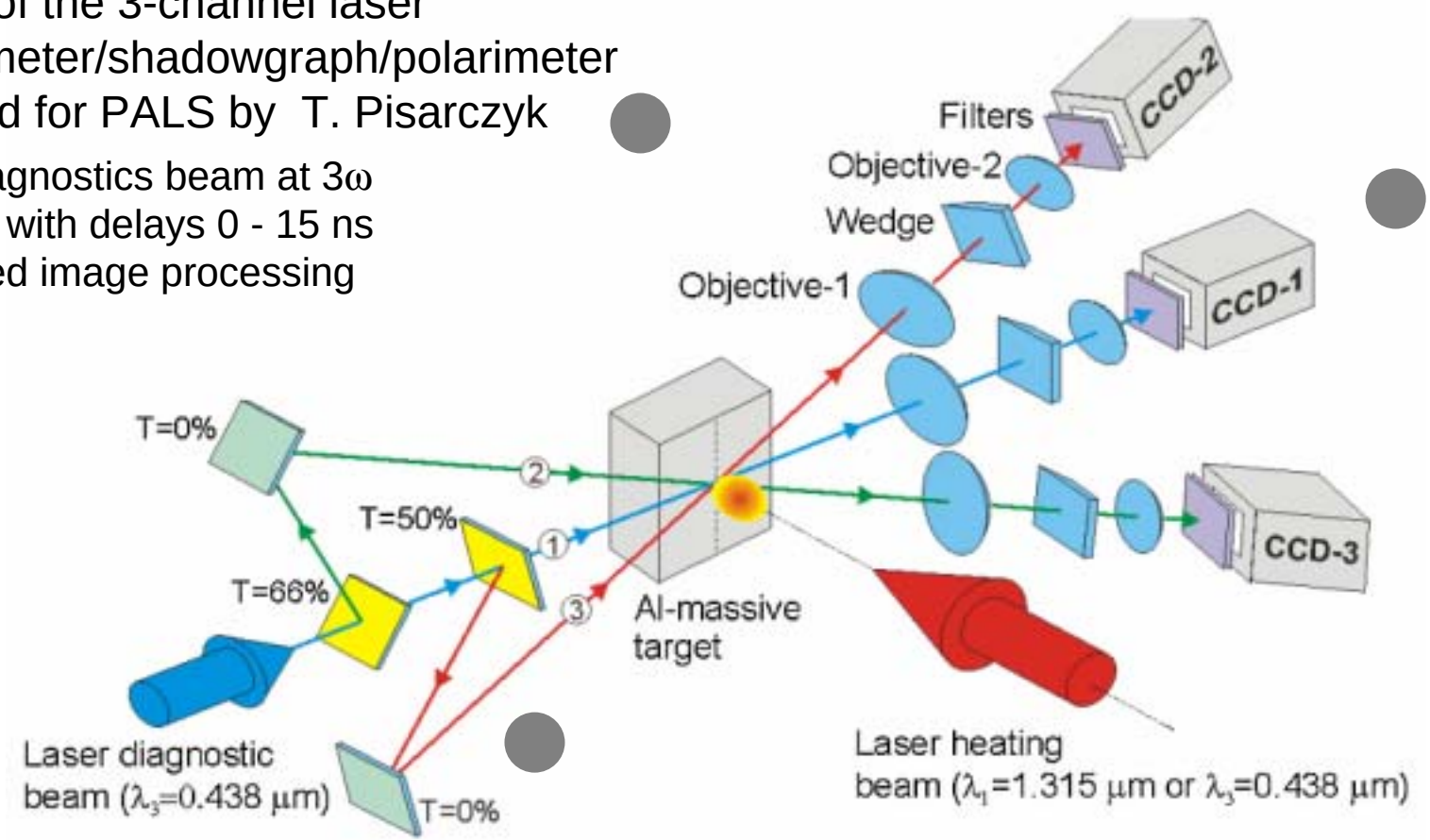
T. Pisarczyk, P. Pisarczyk, A. Kasperzcuk et. al.

- Polish-Czech co-operation
- Essential contribution to the diagnostics of early stages of the plasma expansion

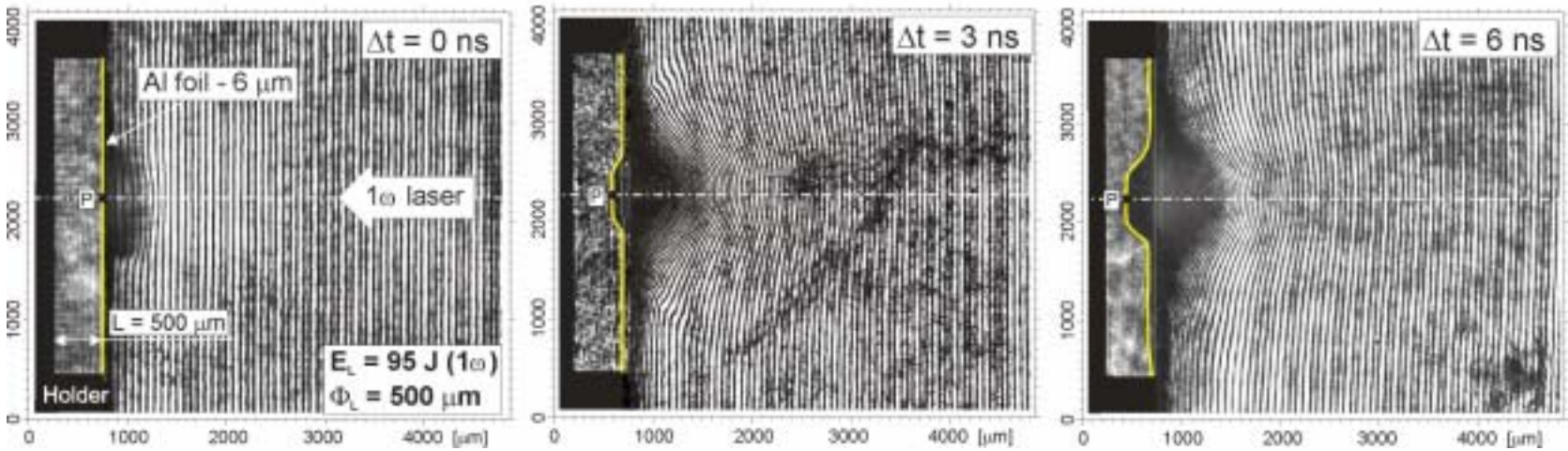
High-quality interferograms of various expanding plasmas

Scheme of the 3-channel laser interferometer/shadowgraph/polarimeter developed for PALS by T. Pisarczyk

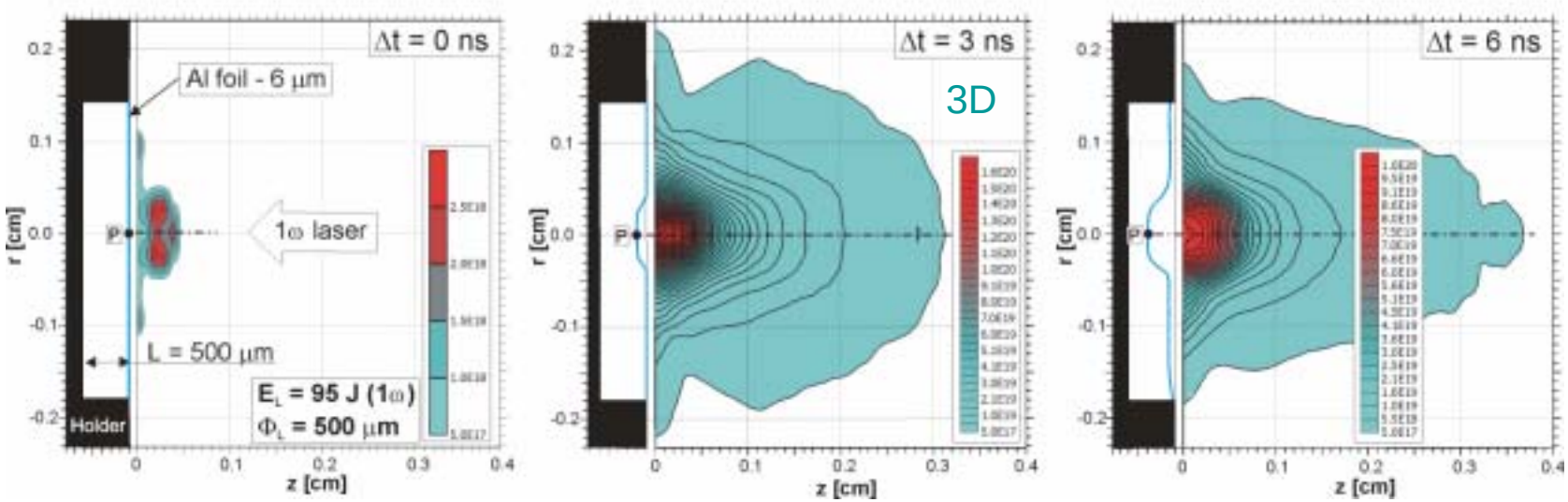
- PALS diagnostics beam at 3ω
- 3 frames with delays 0 - 15 ns
- automated image processing



Fresh results on foam & disc acceleration I



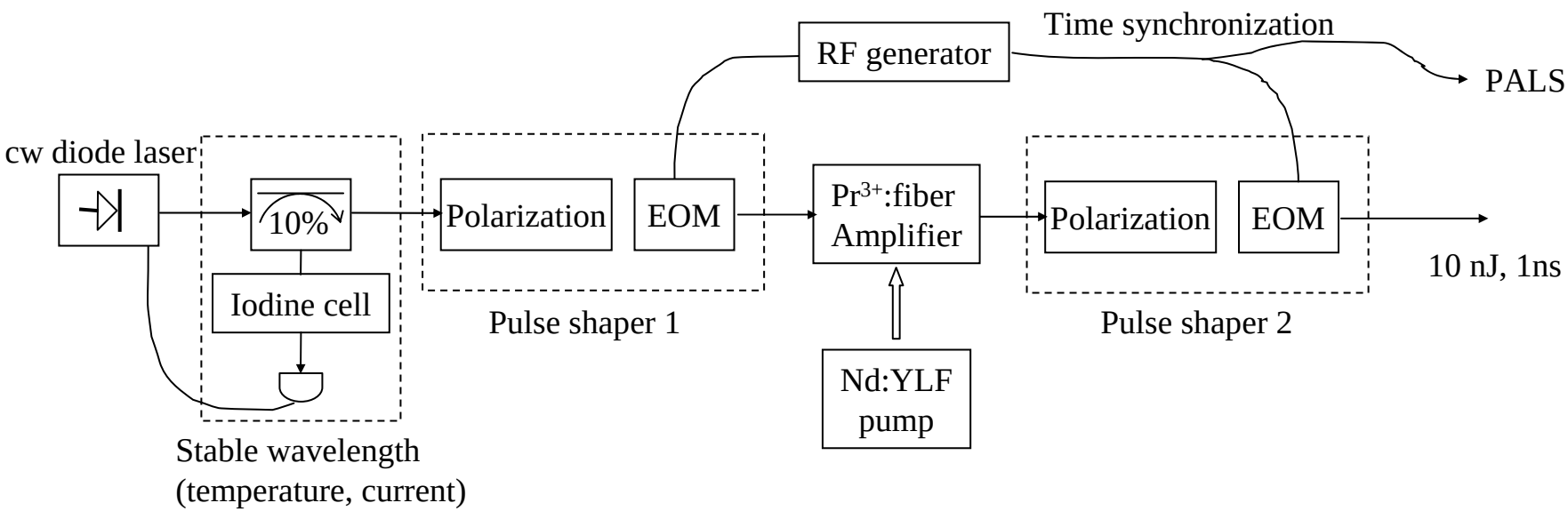
Time sequence of interferograms/shadowgrams of the accelerated Al foil



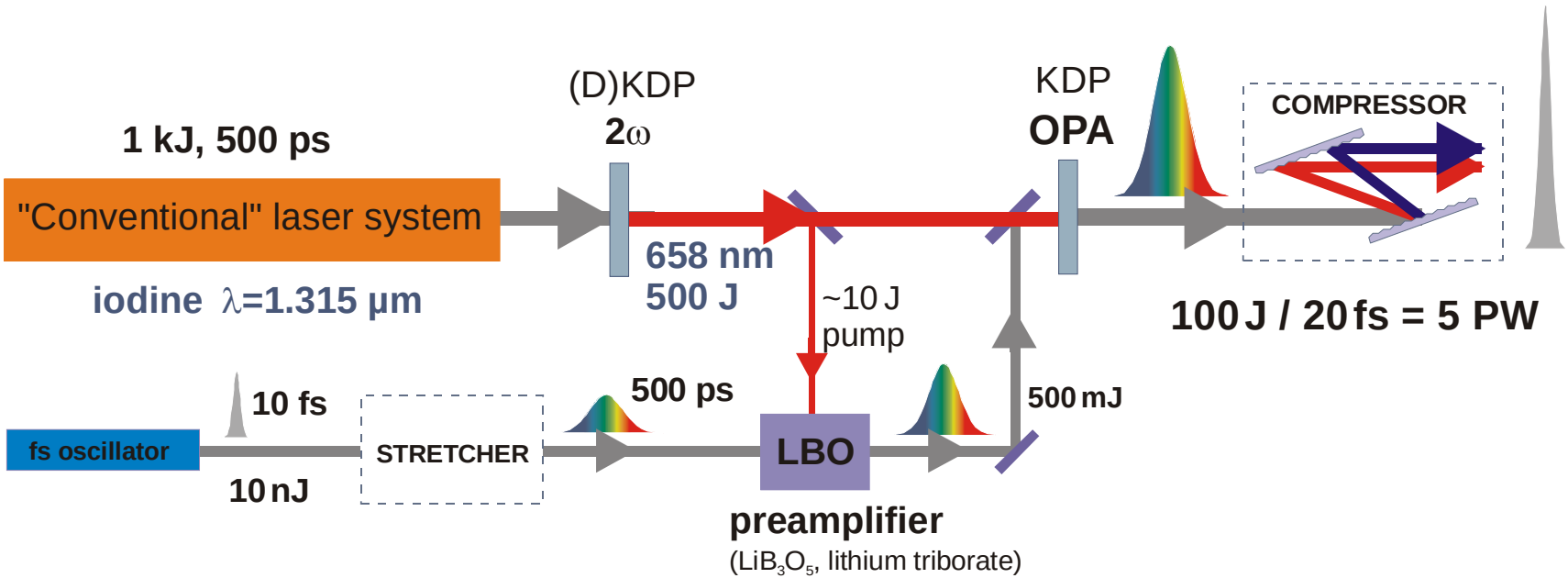
The processed densitograms/contourgrams (by courtesy of T. Pisarczyk)

The foil velocity at the central point P: $3.5 \cdot 10^6$ cm/s $6.2 \cdot 10^6$ cm/s

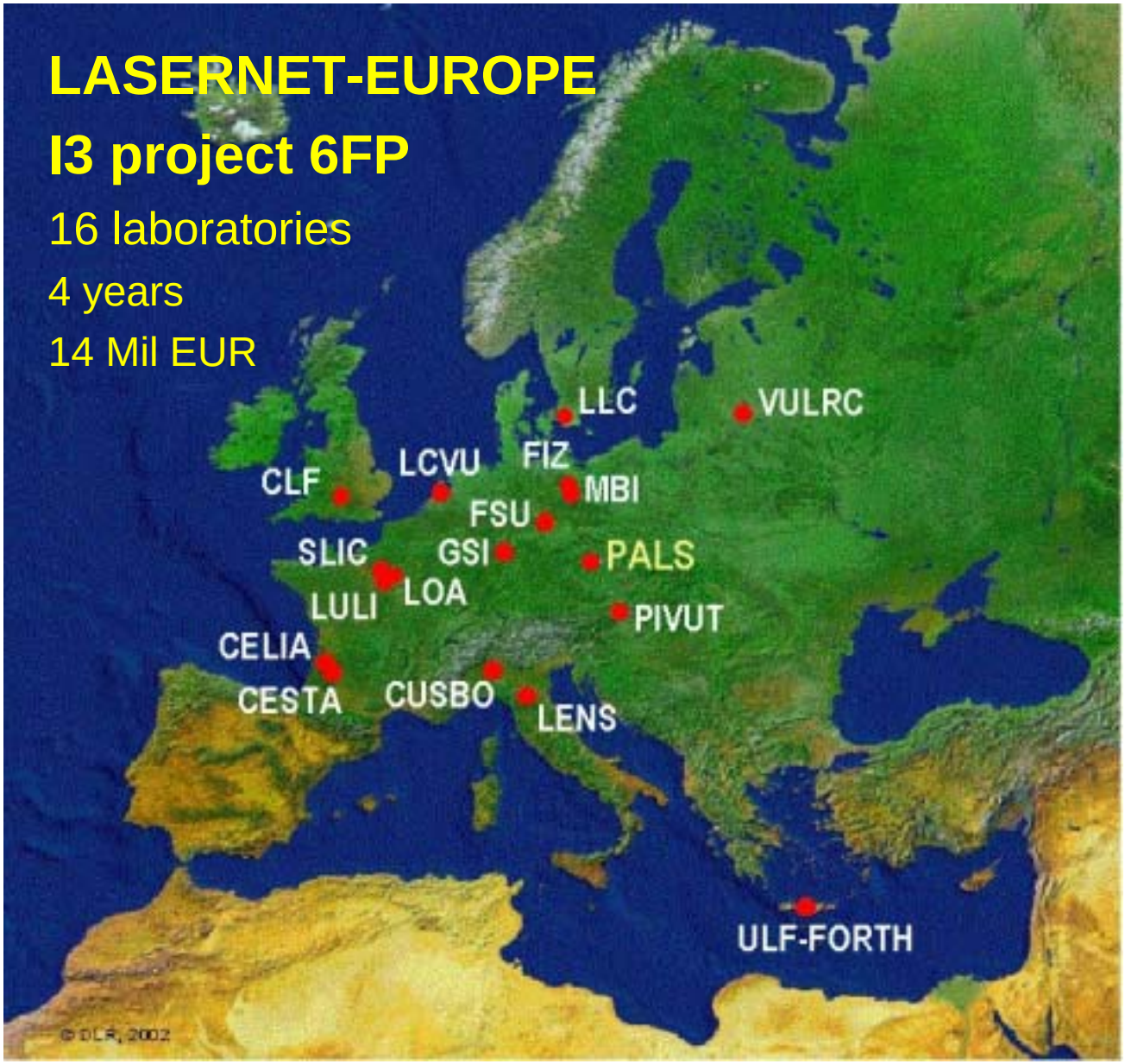
Fiber front-end of PALS of GSI type
Tests directly on PALS, seeded oscillator



Futuristic vision of a full scale implementation of OPCPA on PALS
Calculations I. N. Ross, P. Matousek (RAL), B. Rus (Prague)



PALS in the 6th Framework Programme



Includes:

Access to the laser facilities, incl. PALS

Joint Research Activities:

- **ultra-fast optics (XUV lasers) X**
- **ultra-high power incl. OPCPA**

Networking & administration

Training of students

Contract preparation phase:

September 2003

The PALS laboratory offers laser time to eligible user groups. A novel feature is a possibility to use a coherent x-ray laser beam of record brightness for application type experiments. The domain of very short pulses is gradually approached by the OPCPA upgrade.