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Radiations from a Water Jet Plasma Source

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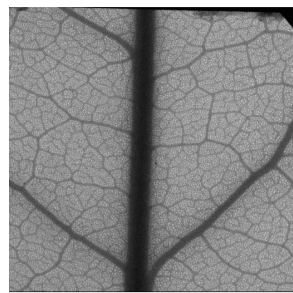
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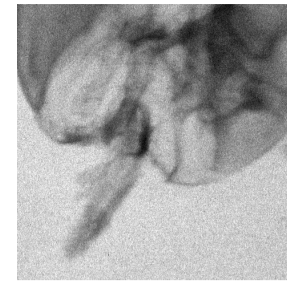
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Wilfred Fullagar, Jens Uhlig, Monika Walczak, Sophie Canton, Claes-Göran Wahlström, Villy Sundström



X-ray shadow image of a leaf

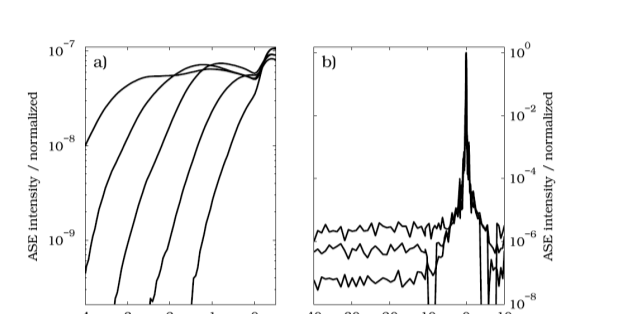
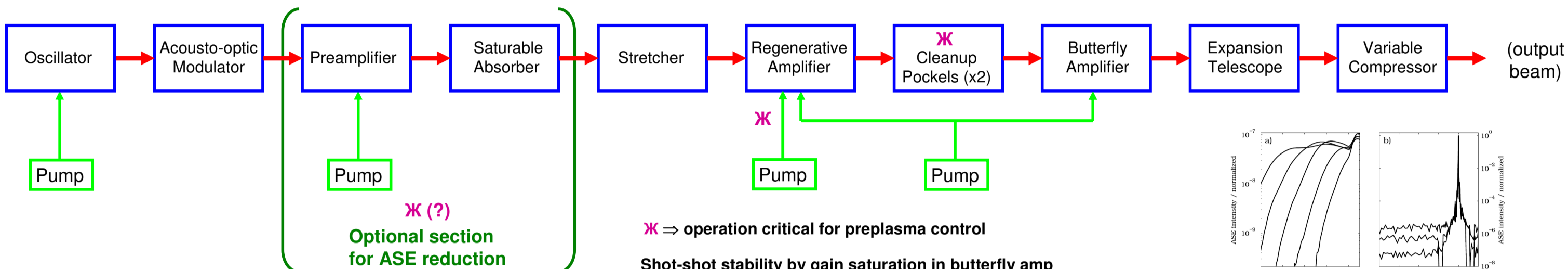
Division of Chemical Physics
Division of Atomic Physics



X-ray shadow image of a fly head

Laser system

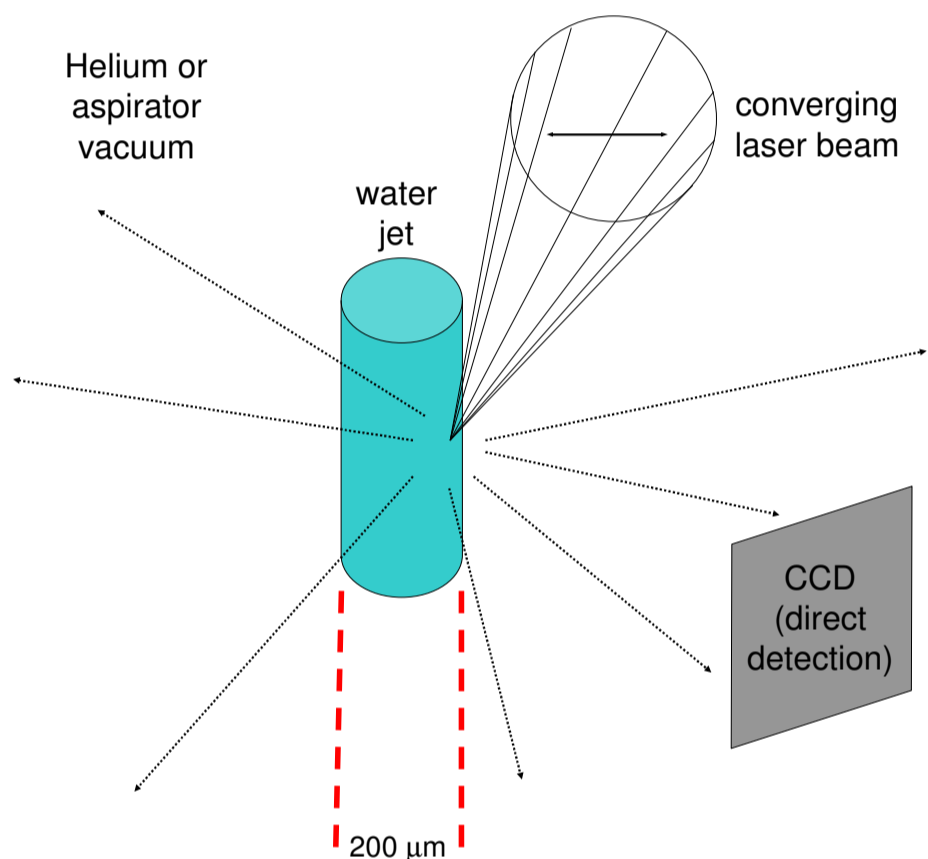
low power branch of LLC terawatt facility (June 2007)



Typical temporal contrast (courtesy Filip Lindau)

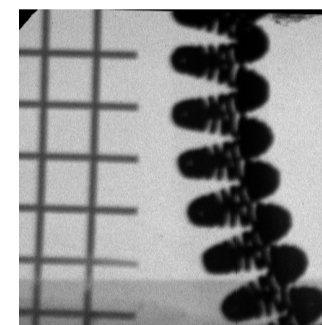
Output beam:
800 nm, ≥ 35 fs, ≤ 300 mJ/pulse, 10 Hz, ~ 4 cm ϕ

X-rays

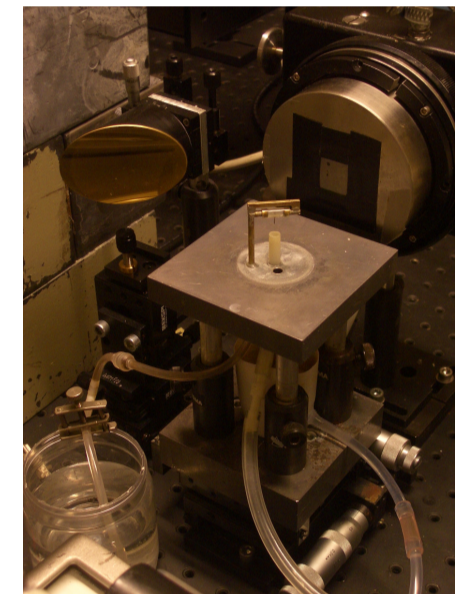


Goals:

- In-house subpicosecond chemical structure dynamics, via
 - pump-probe EXAFS
 - pump-probe Laue crystallography

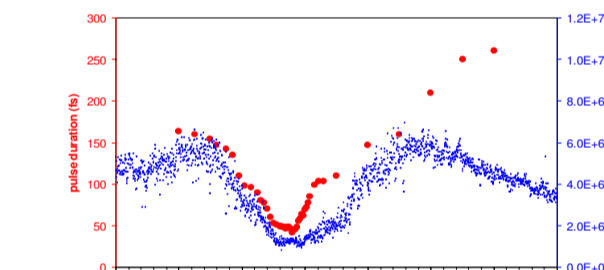


Shadow of ightbulb filament & 250µm Cu grid
Blurring \Rightarrow source ~ 30 µm

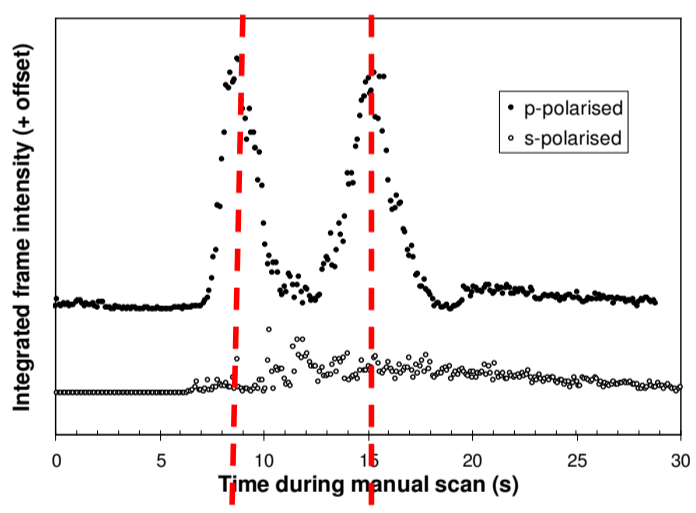


A typical setup, shield chamber removed

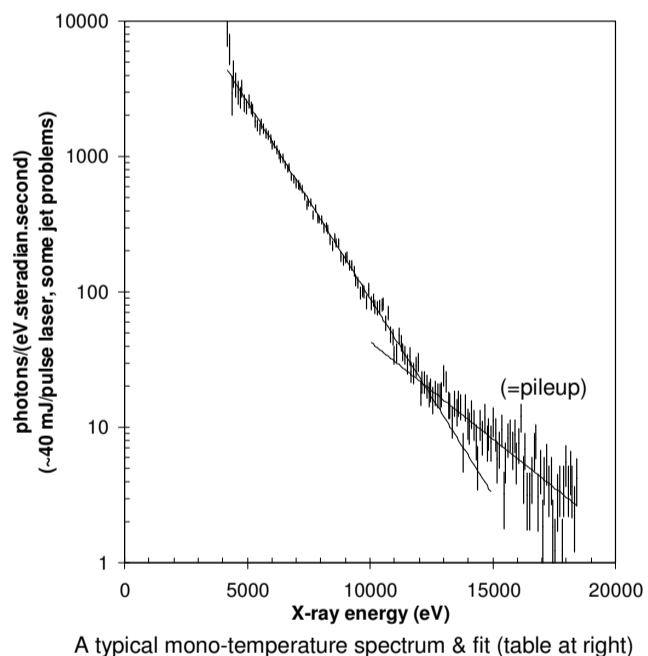
Source ambitions:	This source:
* Everyday local development access	Yes (LLC collaboration)
* Simplicity \rightarrow in-house development & maintenance	Yes
* Broadband radiation	Yes (Maxwellian, $T = 10-50 \times 10^6$ K)
* Sub-picosecond burst	Expected (believed limited by (jet ϕ)/(e- velocity), or laser pulse)
* No emission lines (\rightarrow detection & mechanism issues)	Yes (oxygen $K\alpha$ too soft for typical filter transmission)
* Adequate X-ray flux	Yes (EXAFS) but requires detection development
* jitter-free laser synchronisation	Yes
* Collimation	No (needed for Laue xtlgrphy; see electron beams, below)
* Small source size	Yes (multi-shot images $\Rightarrow \sim 30$ µm in target plane)



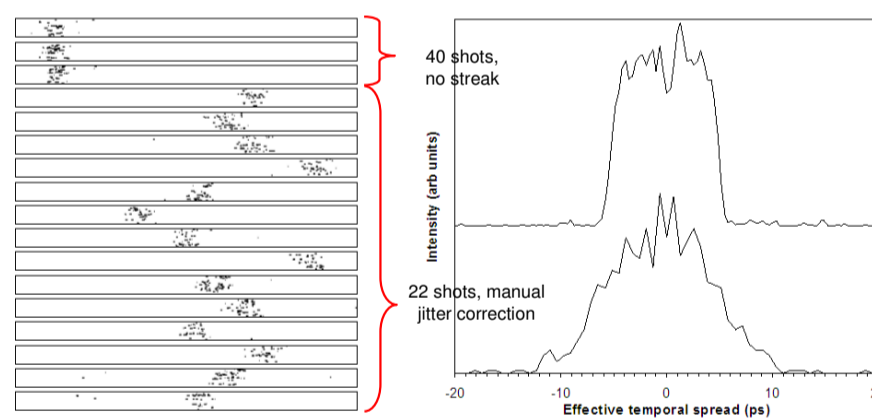
Compressor scan: X-ray yield & autocorrelator FWHM overlaid



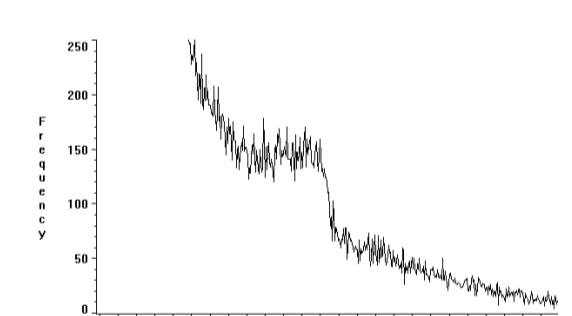
Manual scan of jet through focus



A typical mono-temperature spectrum & fit (table at right)



Instrumental resolution on X-ray streak camera



Single shot Ti $K\alpha$ XAS edge spectrum (5 µm Ti foil)

Adaptable to typical kHz laser

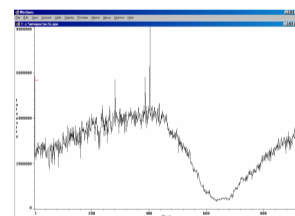
Handy bunch of numbers (corresp. 10 Hz, 1 atm He operation)

Energy/pulse (mJ)	optical pulse duration	N_0 (ph/[eV.sr.sec])	T (K)
40	~ 200 fs (optimum)	71500	17.4×10^6
1.6	~ 200 fs (optimum)	14702	12.7×10^6
40	~ 40 fs (shortest)	29200	11.5×10^6

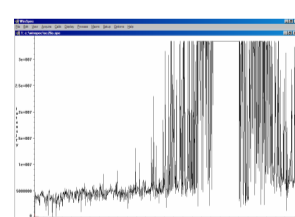
Selected relevant literature:
* R.J. Tompkins et al. Rev.Sci. Inst 69(9), 3113 (1998)
* K. Eidmann et al. Europhys Lett., 55(3) 334 (2001)

Add s-pol prepulse, several 10s ps early, 1:1 pwr ratio
 \Rightarrow X-ray-free, controllable preplasma (vast parameter space)

Electrons



Chirp scan, no prepulse
No electrons
X-rays only, as above

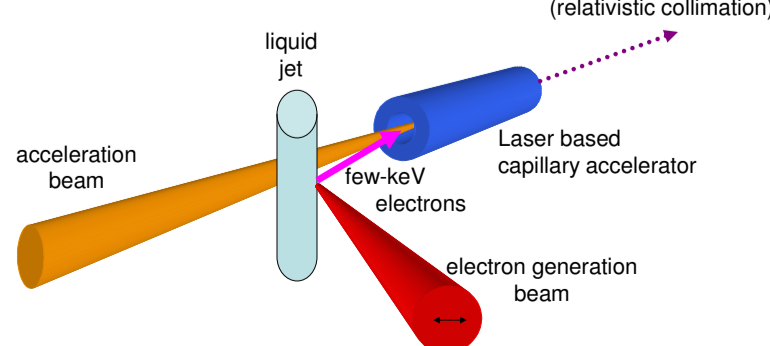


Repeat, with prepulse
e- beams at shortest pulses
Note rescale to include saturation

Strong e- generation when s- & p- pulses briefest. Suggests:
* proton motion during p-pulse unimportant
* e- beam emission = non-resonant phenomenon
* e- beam pulse duration \leftarrow energy range, distance from src

Selected literature precedents:
* S. Bastiani et al. Phys. Rev. E, 56(6), 7179 (1997)
* X.-Y. Peng et al. Chin. Phys. Lett., 21(4), 693 (2004)

Possible future?



Selected relevant literature:
* A. Rousse et al. Phys. Rev. Lett., 93(13), 135005 (2004)
* W.P. Leemans et al. Nature Physics, October(2), 696 (2006)

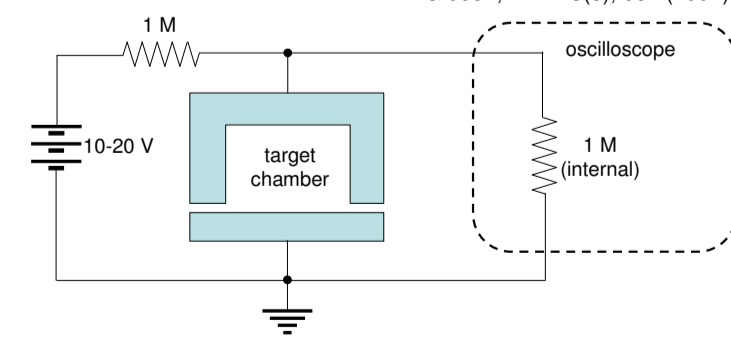
Protons??

H+ emission conceivable with long pulses, high NA focus
For example:



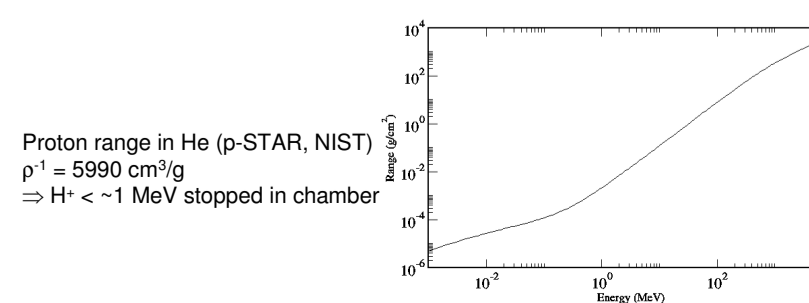
H+ jets moving to left, PIC simulation
F. Brunel, Phys. Fluids, 31(9) 2716 (1988)

Simulated electron spectra with & without mobile H+
P. Gibbon, PRL 73(5), 664 (1994)

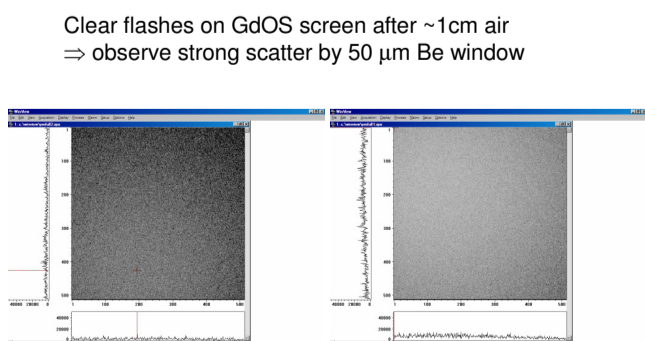


Circuit observes all ionization in chamber \rightarrow strong signal when hitting jet.
But! : only partial correlation with X-ray yield... why?

Protons stopped in chamber by He (\rightarrow ionisation) : see below
However : 524 eV oxygen $K\alpha$ (1/e in He $\rightarrow 12$ cm), & possible other contributions



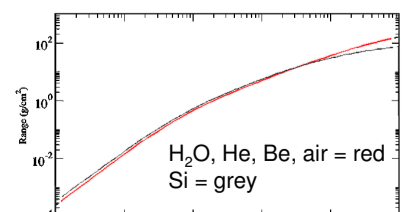
Also! : dramatic change of interaction geometry for continuum X-rays
(typical literature $\Rightarrow 30^\circ - 60^\circ$ incidence for assorted K_α)



Clear flashes on GdOS screen after ~ 1 cm air
 \Rightarrow observe strong scatter by 50 µm Be window

Collimated:
including strong filter scatter & assoc 2ndary radiation $< 10^\circ$ FWHM

Prepulse delay scan through $t=0$. $l \rightarrow r \approx 2$ ns.
 \Rightarrow e-beam requires p-polarised pulse in preplasma.



Electron ranges (CSDA, ESTAR, NIST). ρ^{-1} (cm²/g):
H₂O = 1; He = 5590, Be = 0.541, air = 769, Si = 0.429
Suggests observed beams are 20 – 200 keV.

Generates 5.9keV $K\alpha$ emission line through 5 mm Ti X-ray attenuation foil.