A new quasi mono-energetic ultra short and highly charged electron beam of interest for high energy femtochemistry

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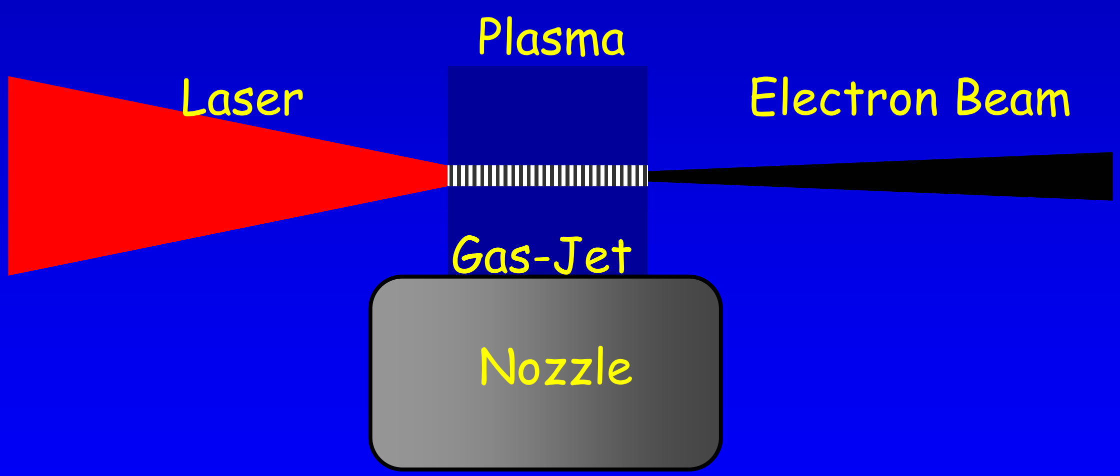

170 +/-20MeV
500 pC
6 mrad

International Conference on
Transient Chemical Structures in Dense Media.
14-16 march 2005

SPL

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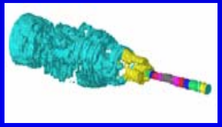
Collaborators



VLPL

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E. Lefebvre (simulations)

T. Hosokai University of Tokyo, Japan

Founding : CARE EEC contract FP6

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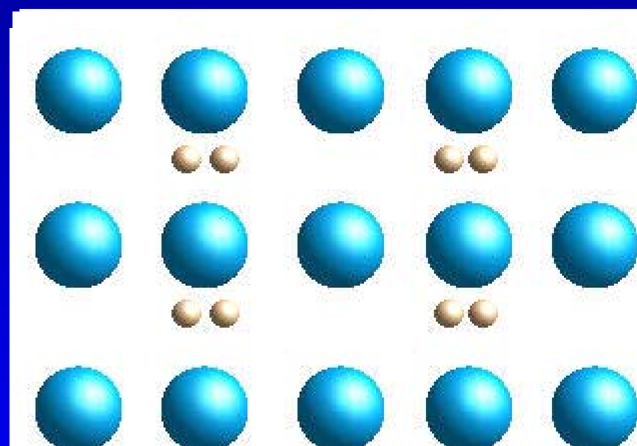
Why use a Plasma ?

- Superconducting RF-Cavities : E_z = 55 MV/m
- Plasma is an Ionized Medium ⟶ High Electric Fields



$$E_z \sim w_p \sim \sqrt{n_e}$$

for 1 % Density Perturbation at 10^{17} cc^{-1} 0.3 GV/m

for 100 % Density Perturbation at 10^{19} cc^{-1} 300 GV/m

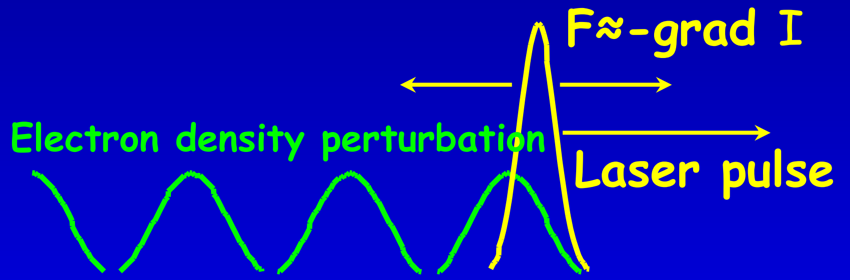
And now > 1TV/m

=> Size and of cost Reduction

e-beam

How to excite Relativistic Plasma waves?

The laser wake field



Phase velocity $v_{\phi_{epw}} = v_{g^{laser}}$
=> close to c
Analogy with a boat

$\tau_{laser} \approx T_p / 2$
=>Short laser pulse

$\tau_{laser} \approx$ 200 fs for $n_e = 10^{17} cm^{-3}$

Tajima&Dawson, PRL79

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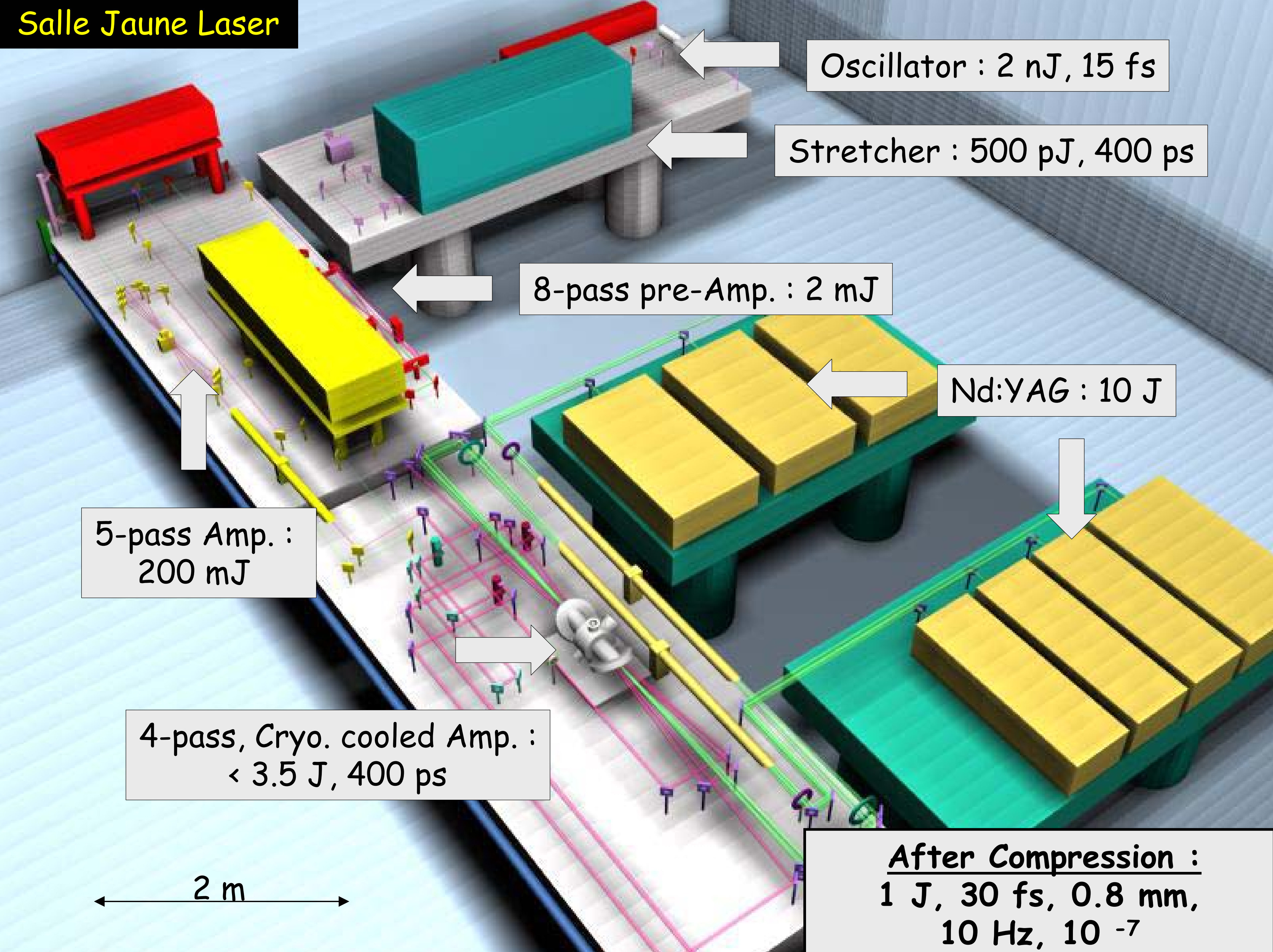
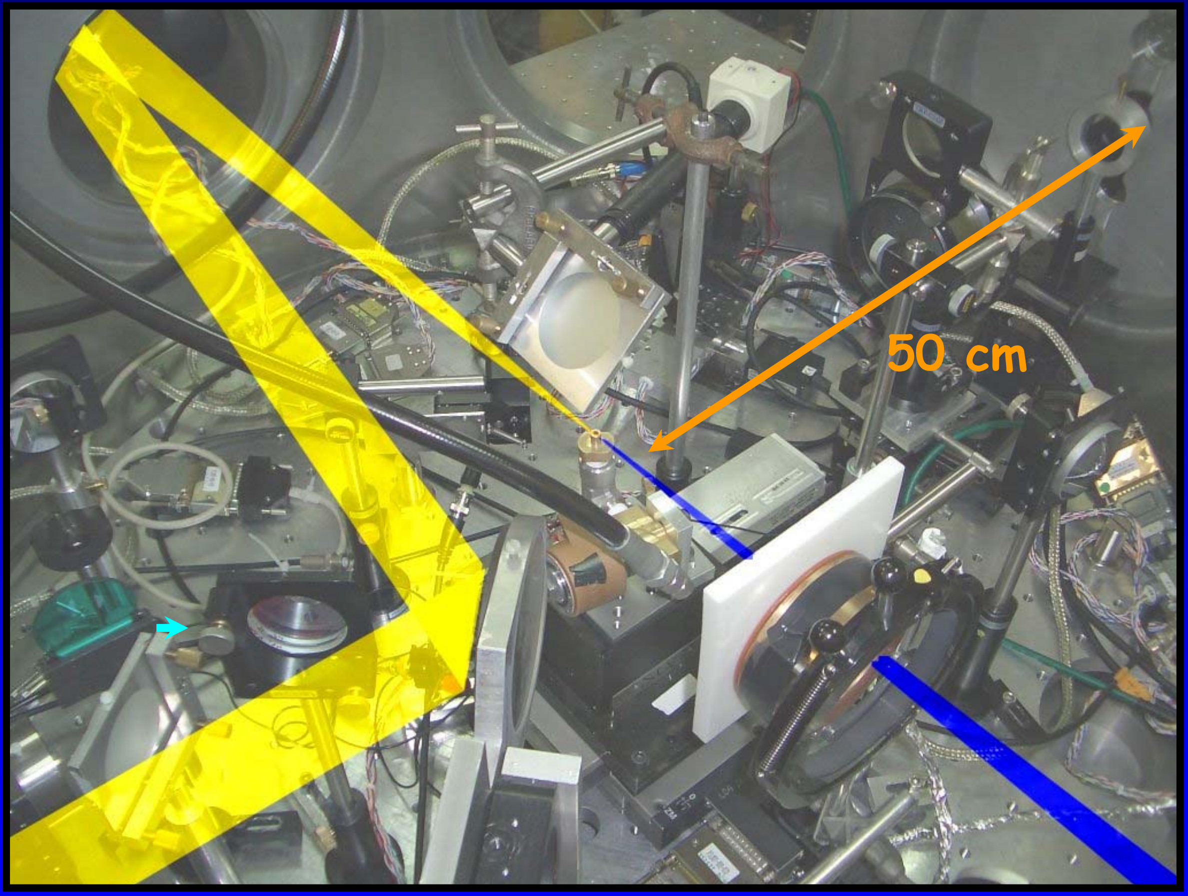
Review of some Former Experiments on Electron Beam Generation

Lab	Year	Process	E_L	Rate	E_e
RAL	1995*	SMLWF	50 J	20 min	44 MeV
	1998	SMLWF	50 J	20 min	100 MeV
NRL	1997	SMLWF	5 J	5 min	30 MeV
MPQ	1999	DLA	0.2 J	10 Hz	10 MeV
LOA	1999	SMLWF	0.6 J	10 Hz	70 MeV
LOA	2001	FLWF	1 J	10 Hz	200 MeV

Large scale, energetic laser, with low repetition rate


Salle Jaune Laser
Oscillator : 2 nJ, 15 fs
Stretcher : 500 pJ, 400 ps
8-pass pre-Amp. : 2 mJ
Nd:YAG : 10 J
5-pass Amp. : 200 mJ
4-pass, Cryo. cooled Amp. : < 3.5 J, 400 ps
2 m
After Compression :
1 J, 30 fs, 0.8 mm,
10 Hz, 10 -7

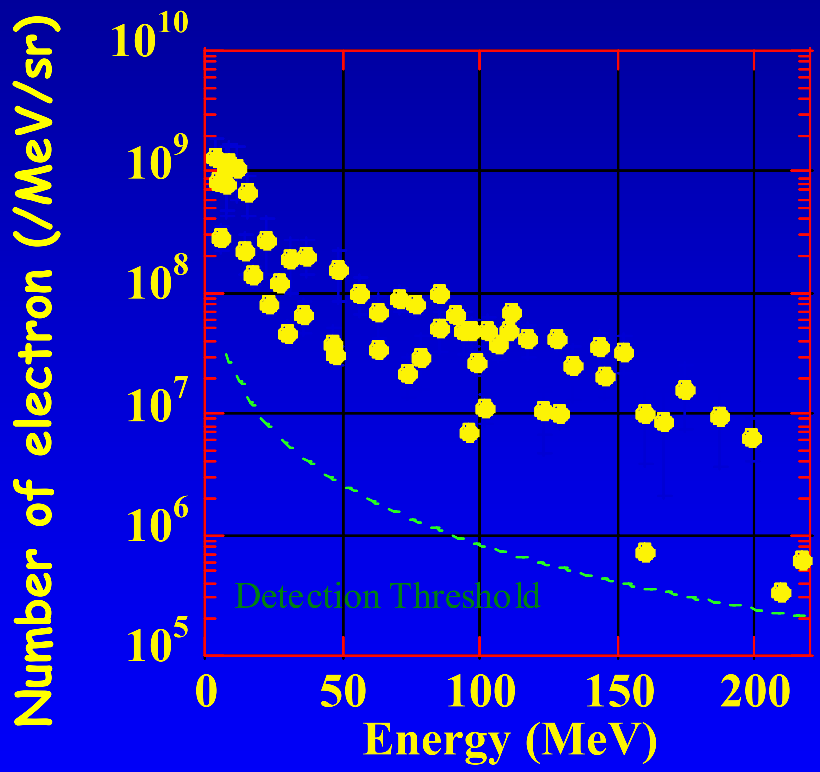
Interaction chamber (inside)



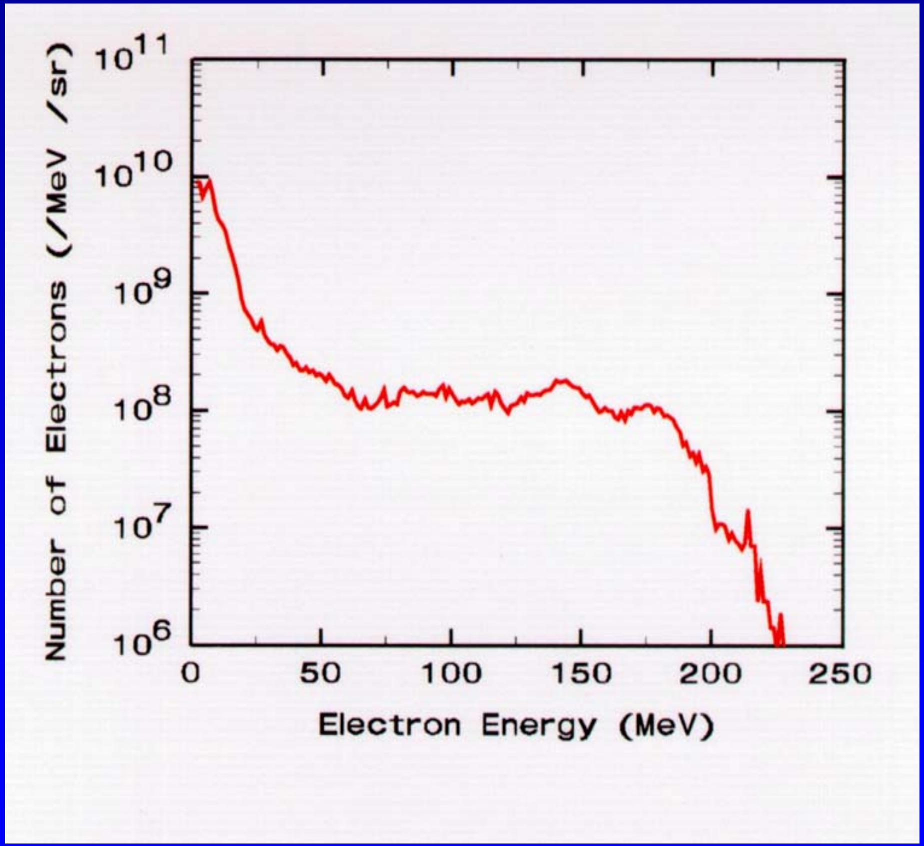
e-beam

Summary of FLWF previous results

Experiments



3D PIC simulations



V. Malka et al., Science, 298, 1596 (2002)

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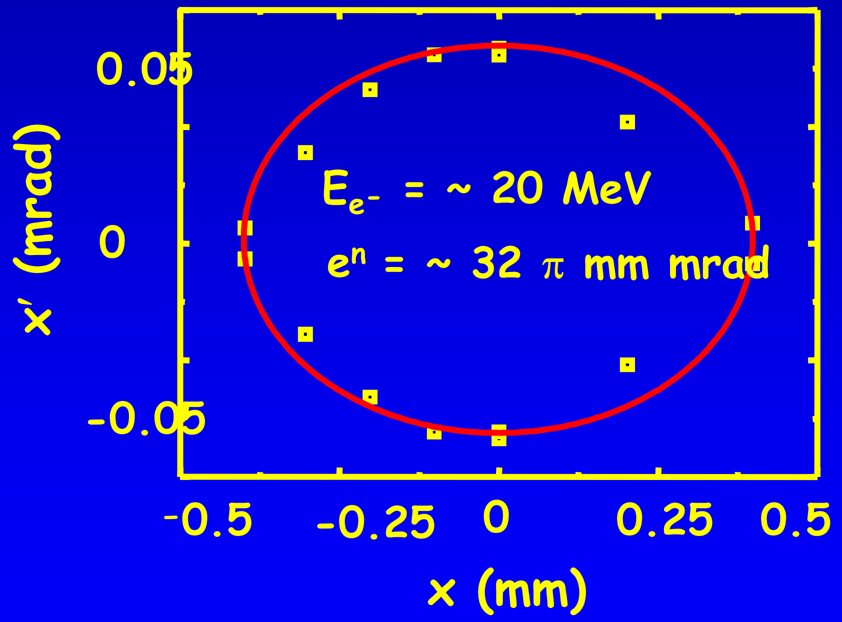
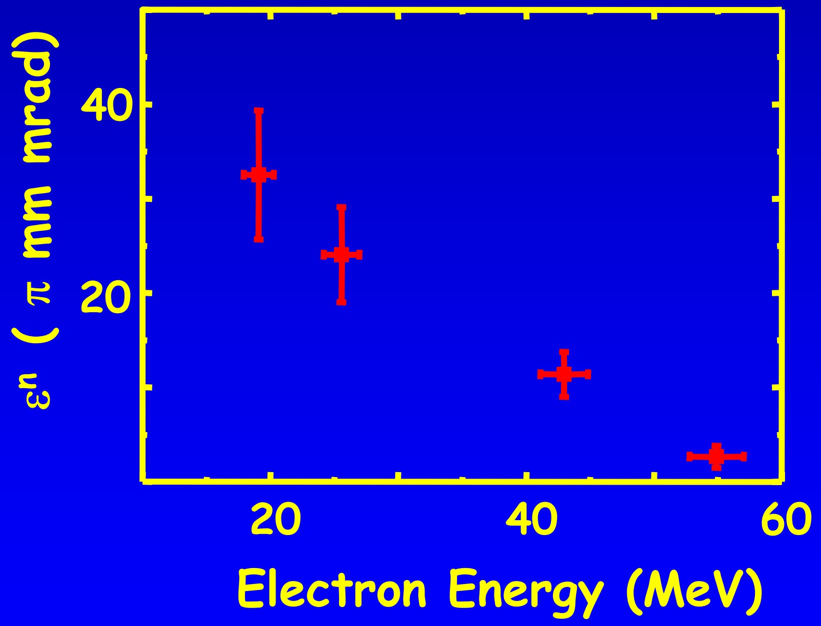
Low Normalized Emittance

Emittance is indeed comparable with todays Accelerators

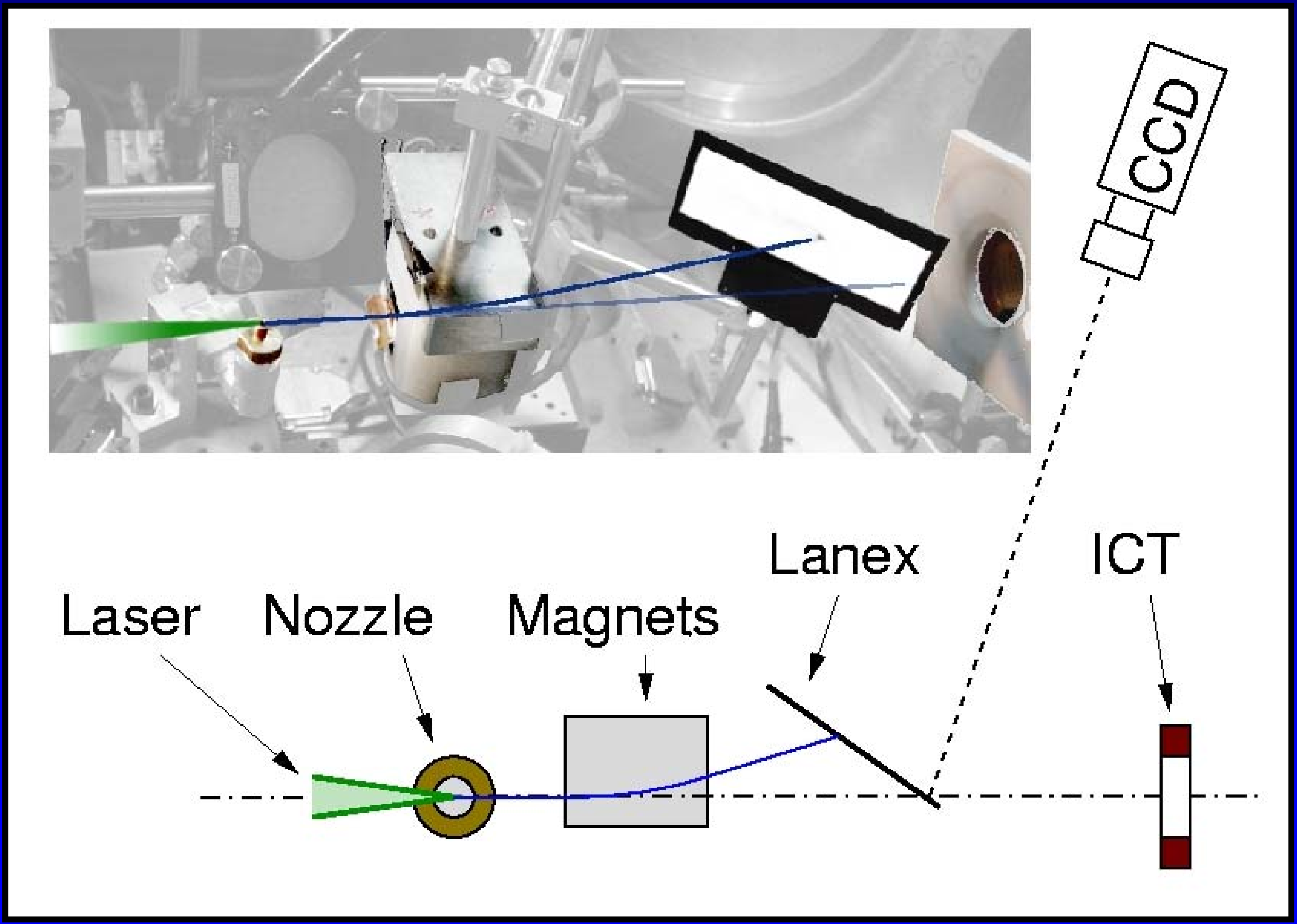
→ E_{e^-} = ~ 55 MeV → ε^n = ~ 3 π mm mrad



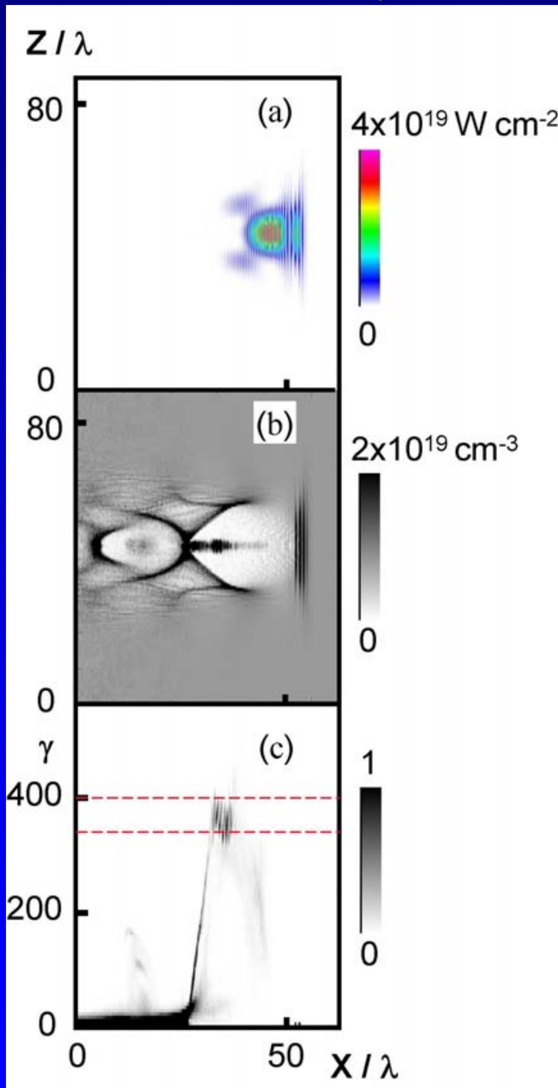


S. Fritzler et al., PRL 04

Experimental Setup : single shot measurement

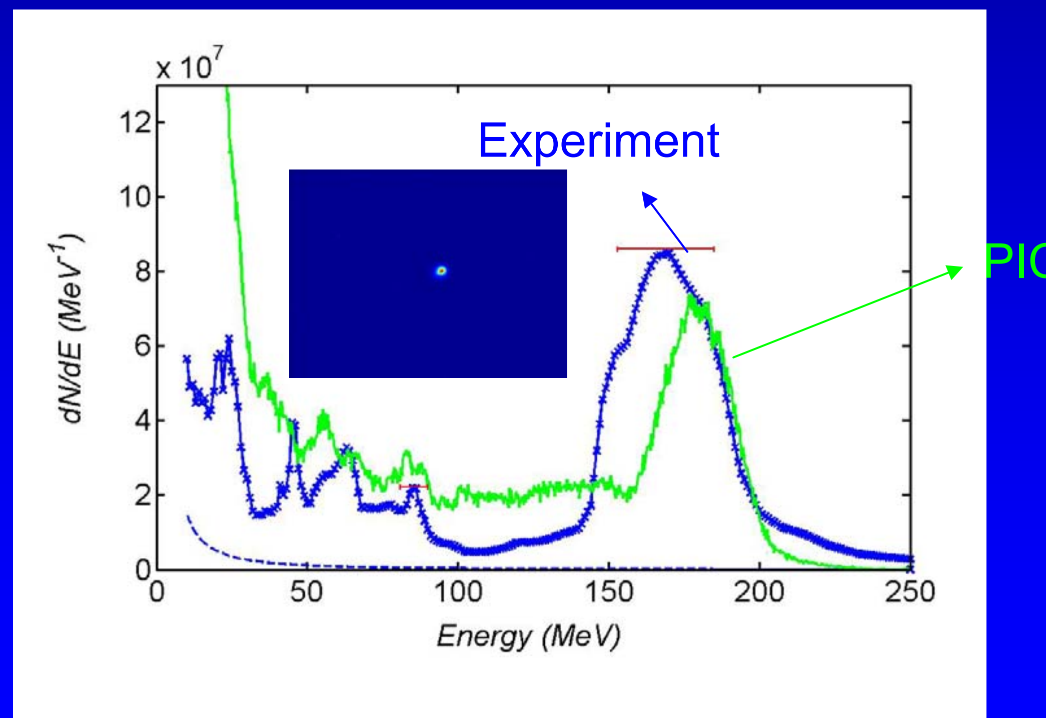


Recent results on e-beam : Energy distribution improvements



Charge in [150-190] MeV : (500 ±200) pC

Divergence = 6 mrad



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J. Faure et al., C. Geddes et al., S. Mangles et al. , in Nature 30 september 2004

Laser particle acceleration could help in reducing the size of accelerators

- fs/ps :higher rep. Rate, lower cost, better e-beam
- Laser particle acceleration has been demonstrated
    - Energy gains of 1 MeV to 200 MeV
    - E-fields of 1 GV/m to 1000 GV/m
    - Good quality
- And now : mono energetic high quality e-beam
- Bullet regime : promising for multi or single stage accelerator (charge, duration)

- Next Step:
    - Stability & reproducibility
    - Electron sources up to ≈ 1 GeV, 1cm (nC, <1 ps)
    - Compact X ray beam and compact (synchrotron, XFEL)

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Some Applications ...

1) Based on the ultra short property of the electron bunch

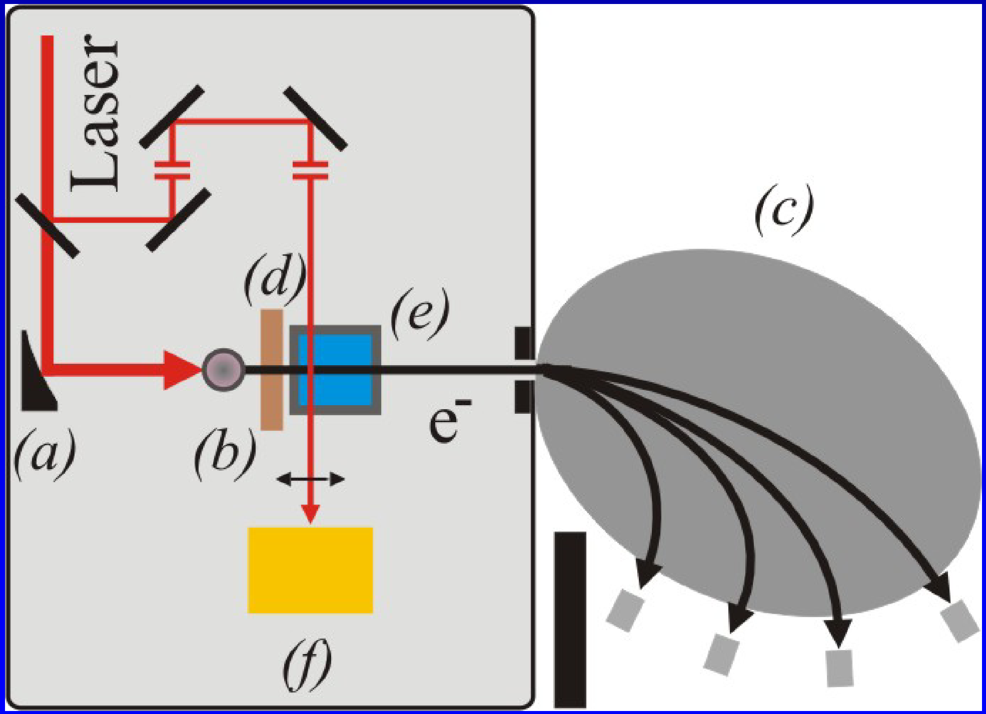
Chemistry

Radiolysis

Some applications : 1) Based on the ulra short duration of the e-bunch :

$$H_2O \xrightarrow{e^-} (e^-_s, OH\cdot, H_2O_2, H_3O^+, H_2, H\cdot)$$

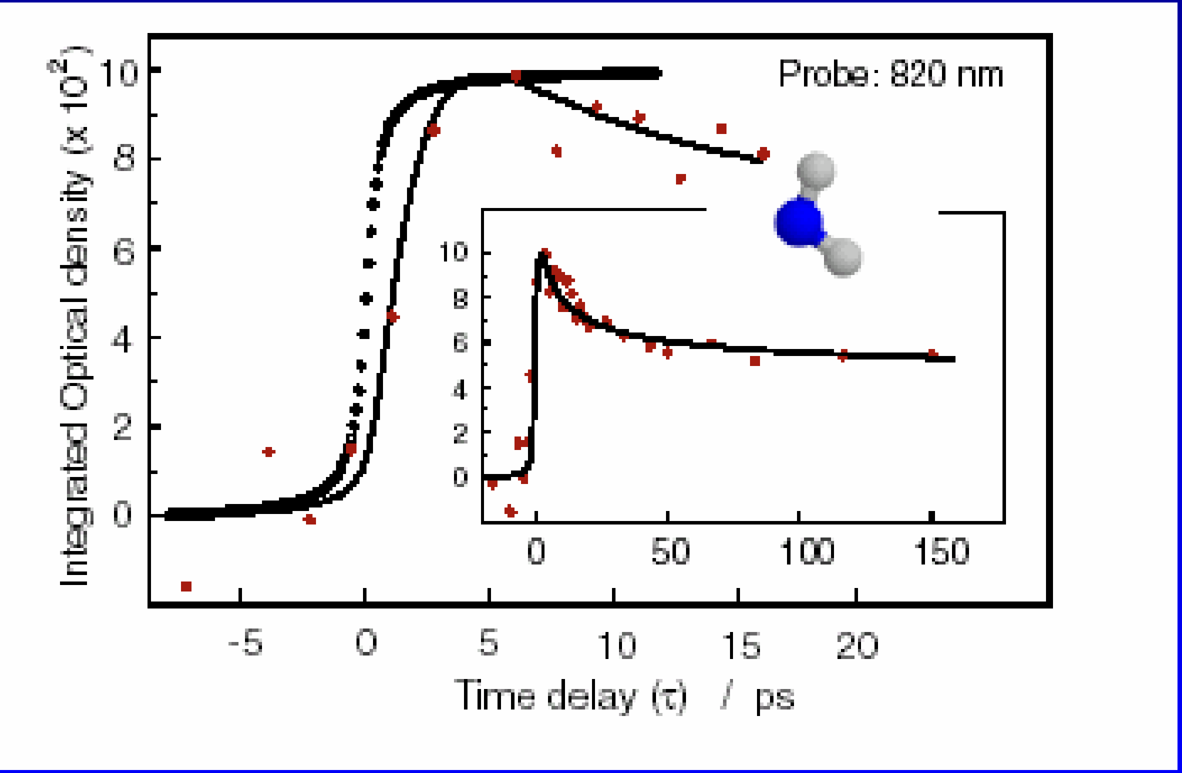
Very important for:
- Biology
- Ionising radiations effects



In collaboration with Y. Gauduel 's group

Recent results on Femtolysis :

Water radiolysis with femtosecond electron pulses



B. Brozek-Pluska et al., Radiation and Chemistry, 72, 149-159 (2005)

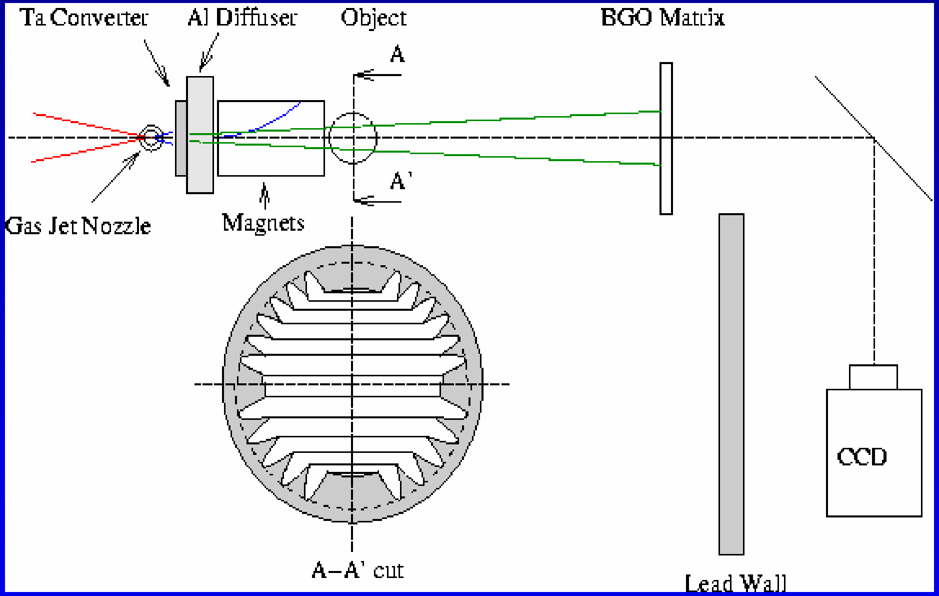
Some Applications ...

2) Based on the collimated property of the electron beam

<u>Non destructive Material inspection</u>

γ Radiography

Example of applications : on the spatial quality benefit High resolution γ radiography



2.5mm tantalum at 3mm of the nozzle center

Aluminium 7.5mm thick to scatter electrons

BGO screen at 1.6m from the nozzle, 600 μm pixels size

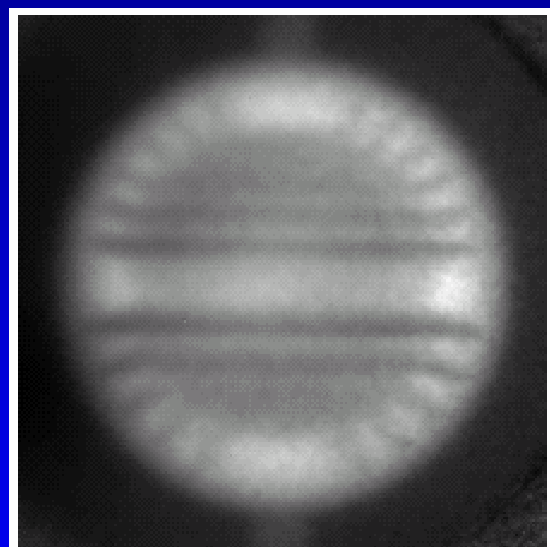
17cm magnet length (B of 0.1T)

20 mm diameter object in Tungsten, at 35cm of the nozzle

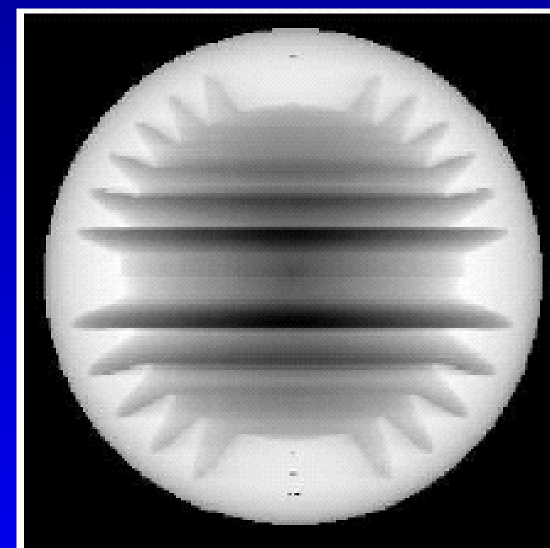
In collaboration with L. Le-Dain, S. Darbon from CEA Mourainvilier and DAM

γ-radiography results

Higher resolution: of the order of 400 μm



measured



calculated

Y. Glinec et al. , Phys. Rev. Lett. 94 (2005)

Some Applications ...

X-rays: diffraction
medicine
γ-rays: radiography

Medicine
Radiotherapy
Proton-therapy
PET

Electrons and Protons
generated by
Laser-Plasma
Interactions

+

X ray Larmor
X ray laser

Accelerator Physics

Chemistry

Radiolysis

A revolution is coming…one of the most evolving field in Science, a wonderful tool for academic formation

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