Coherent XUV radiation with conventional lasers

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OUTLINE

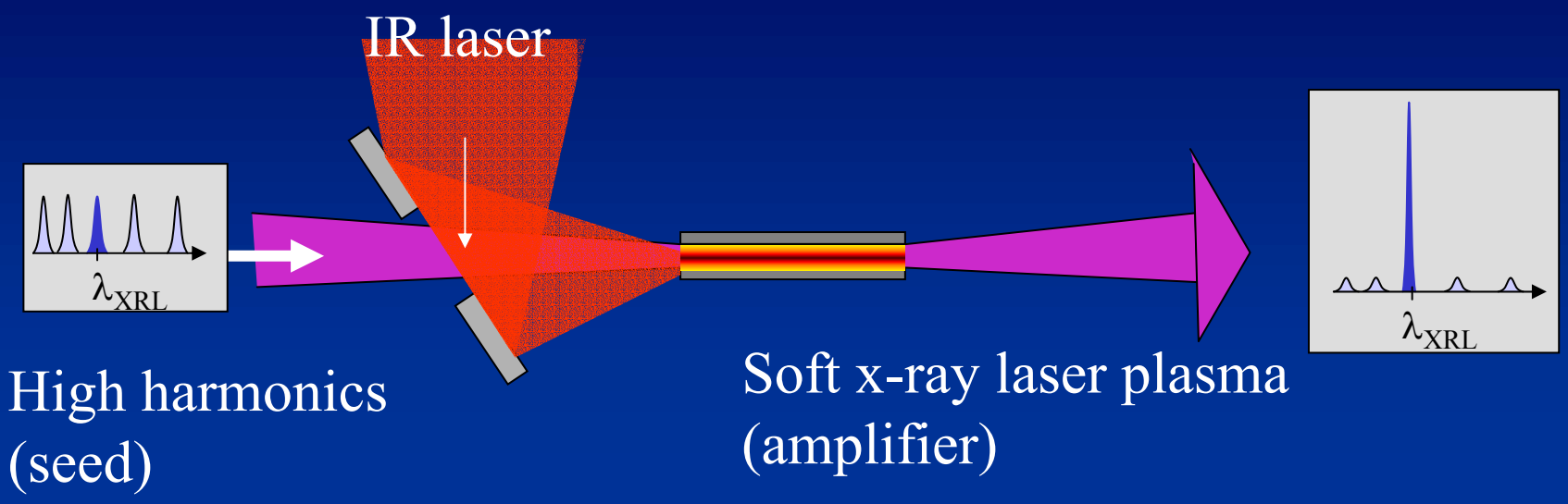
- Laser-driven XUV sources vs FEL
- Schematic description of the experiment
- Results of the experiment with gas amplifier
- Modelling of solid amplifier
- From XUV to x-rays
- Conclusion

Laser-driven XUV sources vs FEL @30 nm

	XUV laser	High Harmonics	VUV FEL
Duration	$\geq$ 2.5 ps	< 20 fs	100 fs
Energy	$\leq$10 mJ	< μJ	40 μJ - 1 mJ
Polarisation	No	Full (linear)	Full (linear)
Spatial coherence	weak	full	80%
Wave front	Good for gas	good	good

XUV lasers of second generation

Choice of the amplifier.



- Solid target :

⊕ High density of emitters

⊖ strong refraction, small gain zone, gain position ?

- Gaseous target : Optical field ionisation XUV lasers

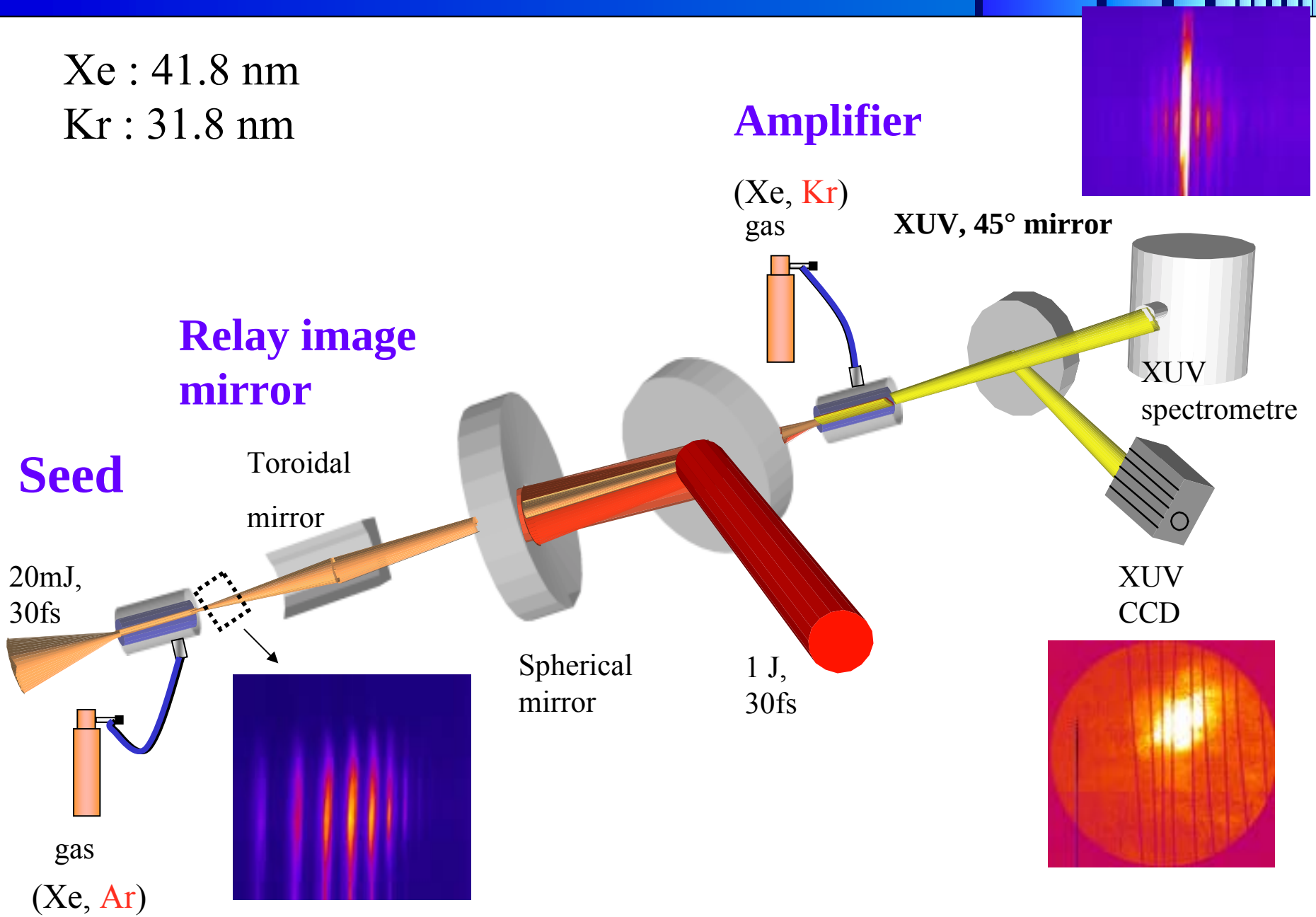
⊕ No réfraction, gain zone is known

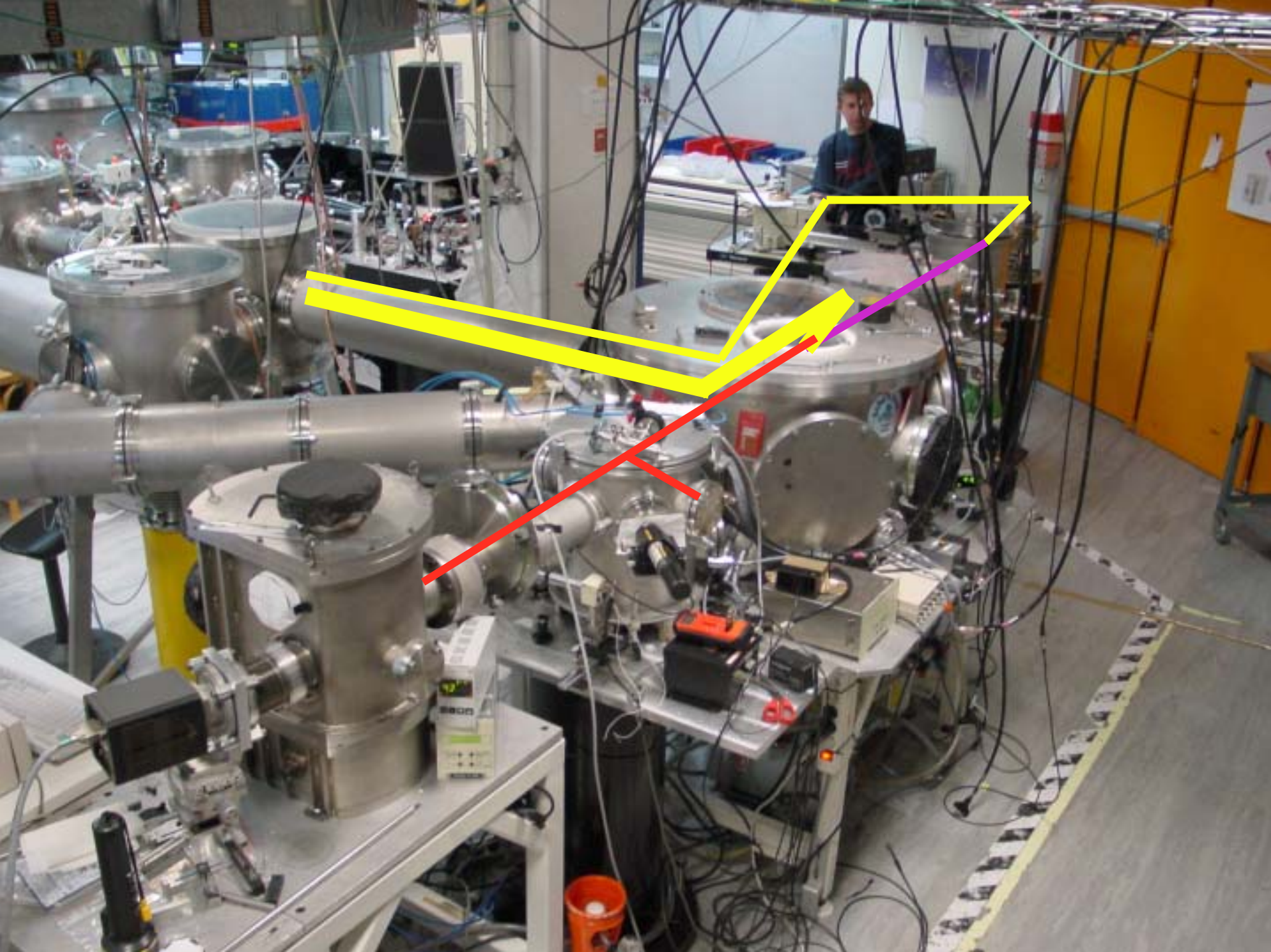
⊖ Low density emitters

Ph. Zeitoun et al, Nature, in press

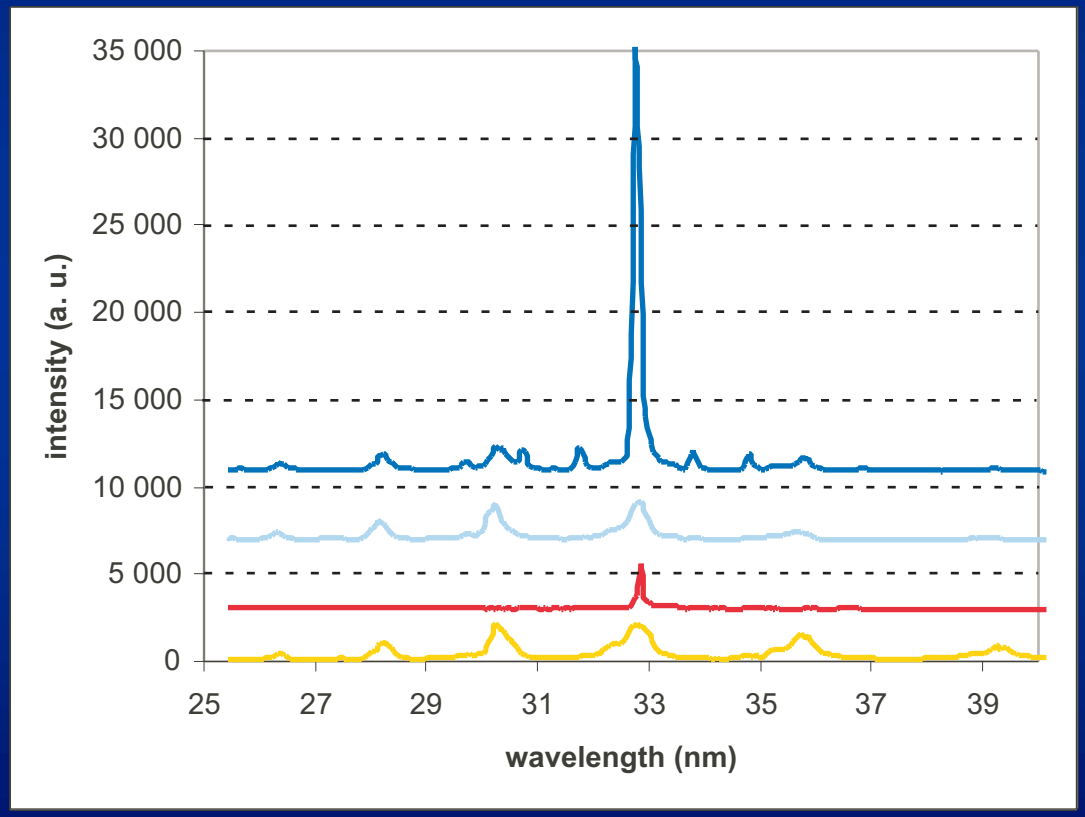
Schematic description of the experiment

Xe : 41.8 nm
Kr : 31.8 nm





The amplification factor was as high as 200



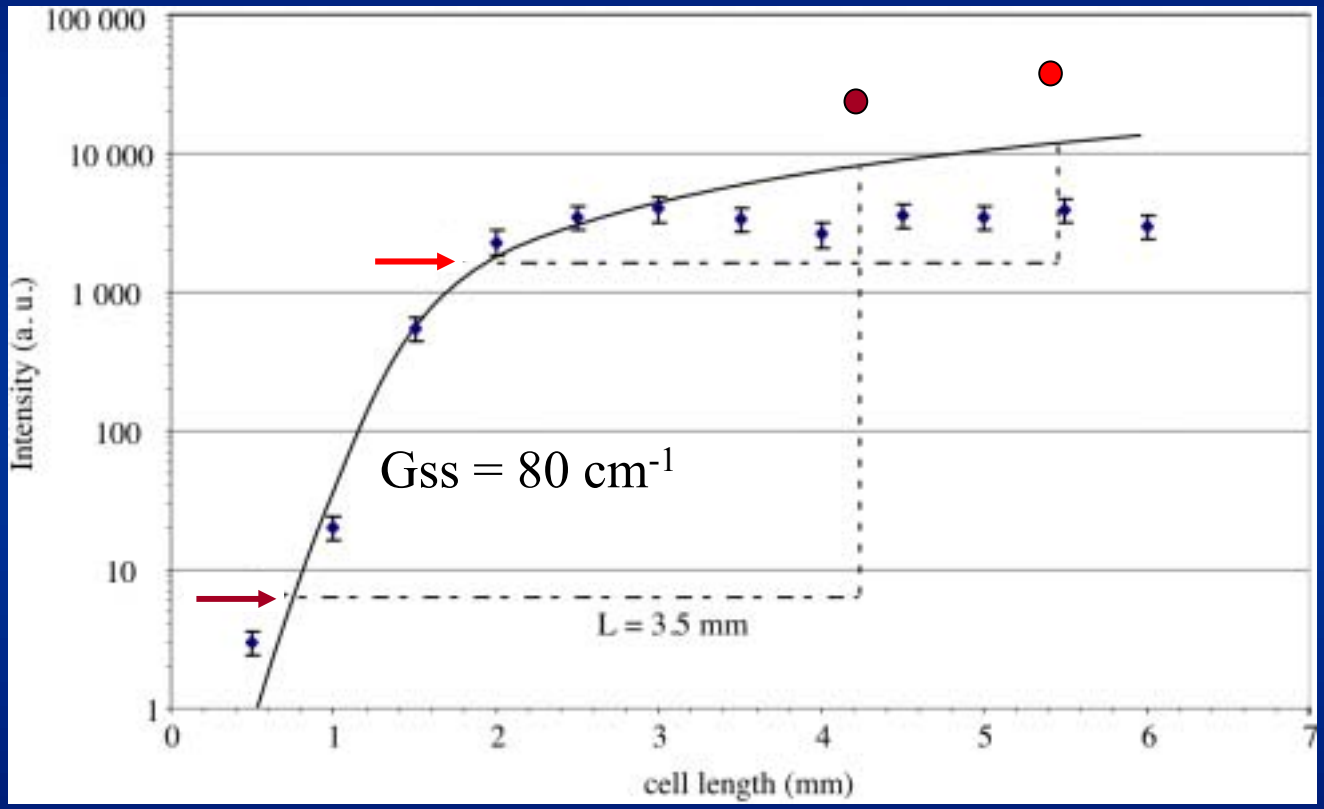
HHG + XUV laser synchronised

HHG + XUV NOT synchronized

XUV laser alone

HHG alone

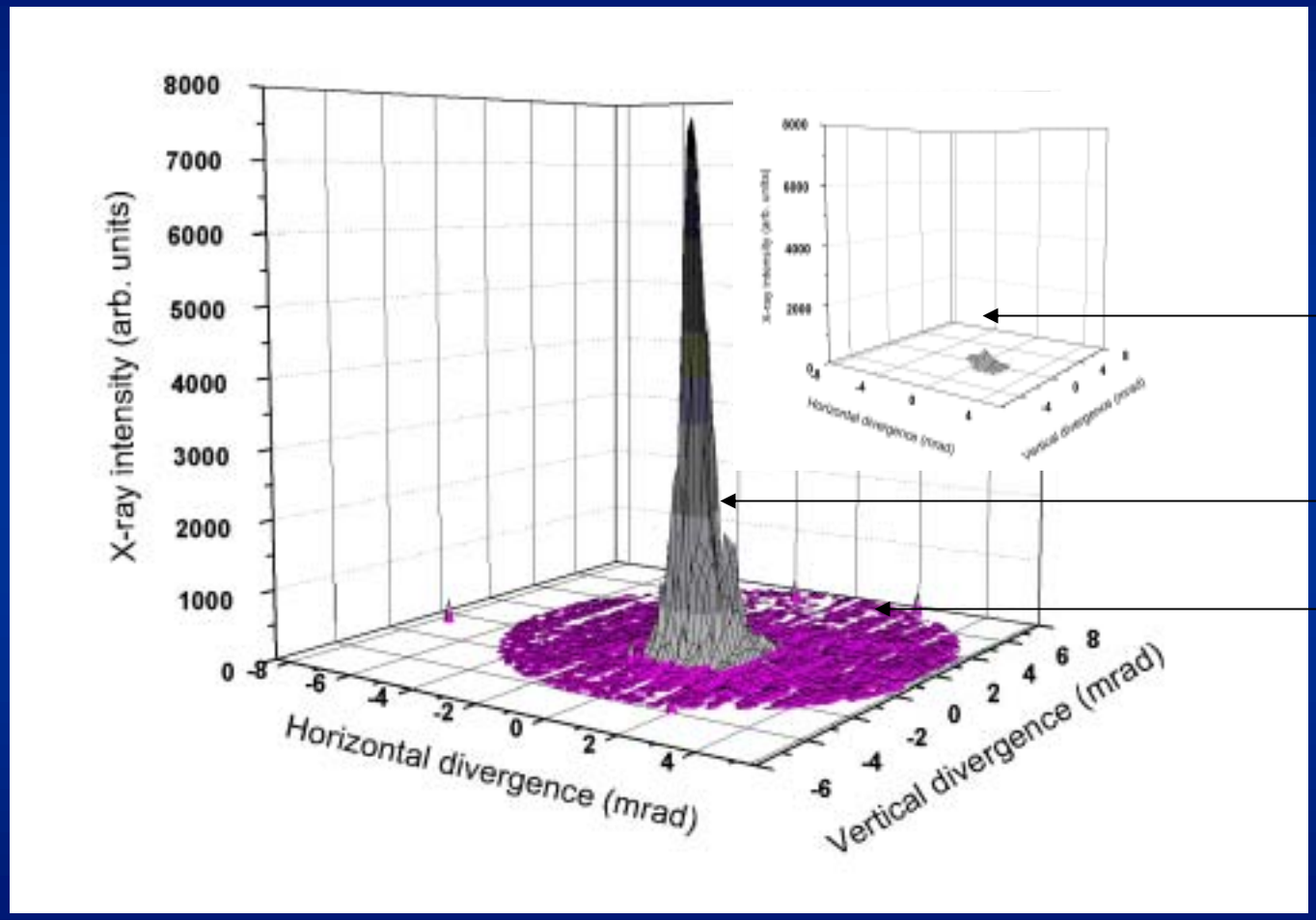
The amplification depends on the level of seeding

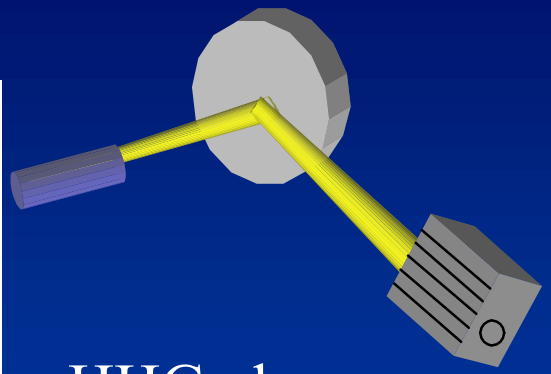


Iinj~Isat/100 : strong amplification (x200)

Iinj ~4*Isat : low amplification (x20)

Beam metrology : cross- section





HHG alone

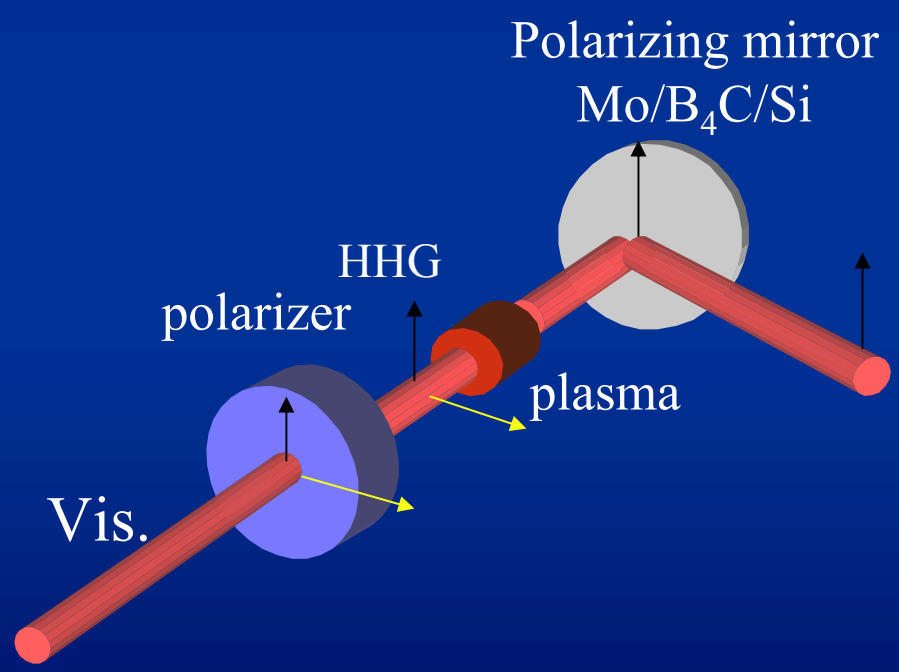
Seeded XUV laser

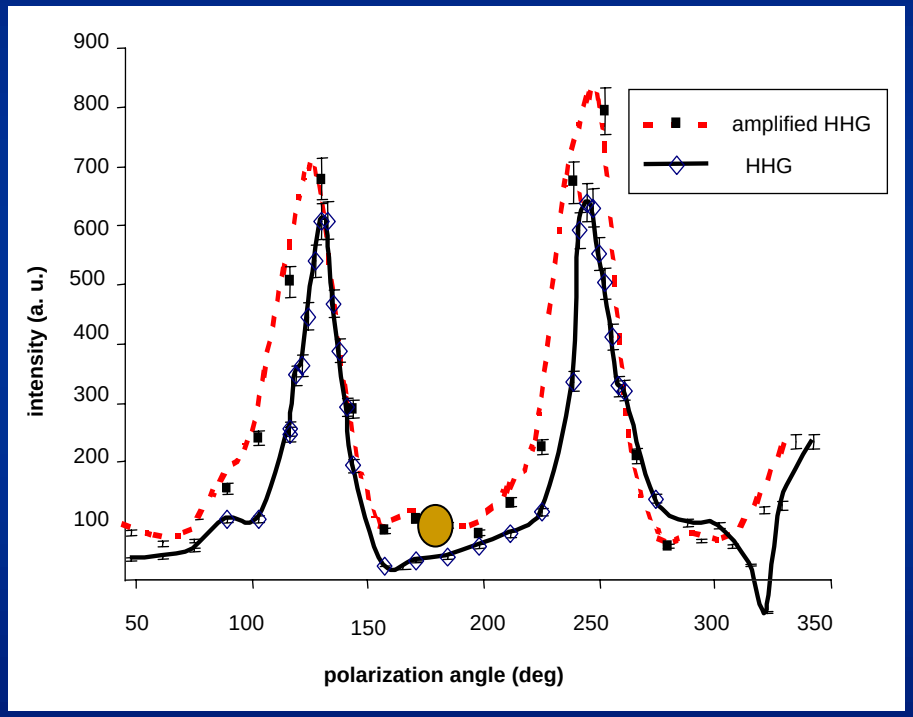
ASE XUV laser

Divergence of the seeded XUV laser : ~1mrad

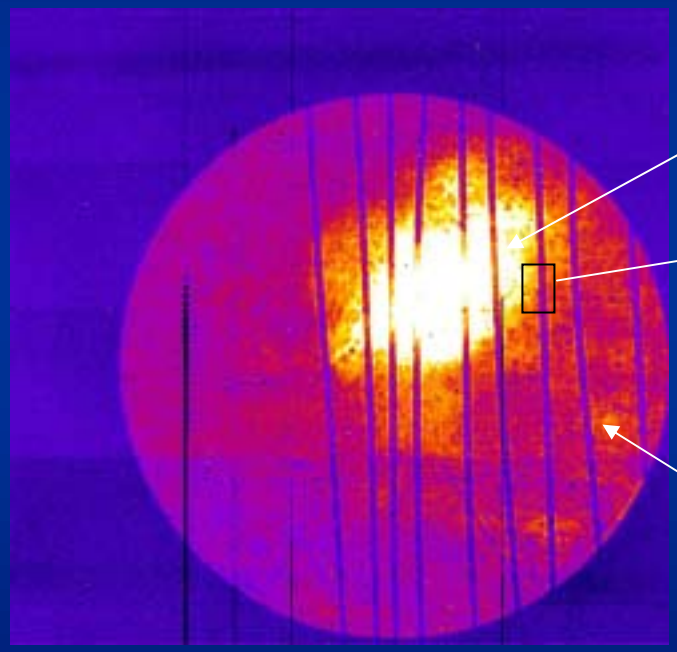
Energie of the seeded XUV laser : ~ 1 μJ

The polarization remains after amplification



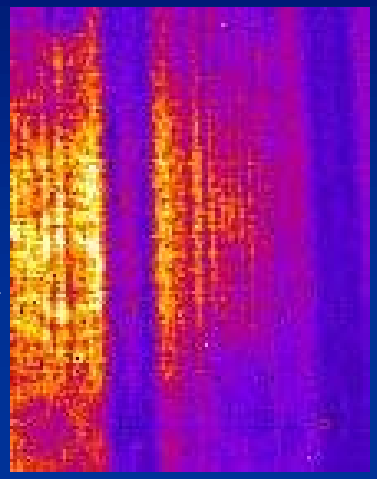


The seeded XUV laser is highly coherent



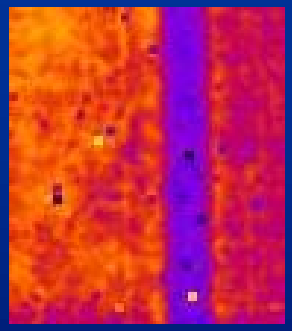
Seeded XUV laser

ASE



diffraction fringes

coherent



weak coherence

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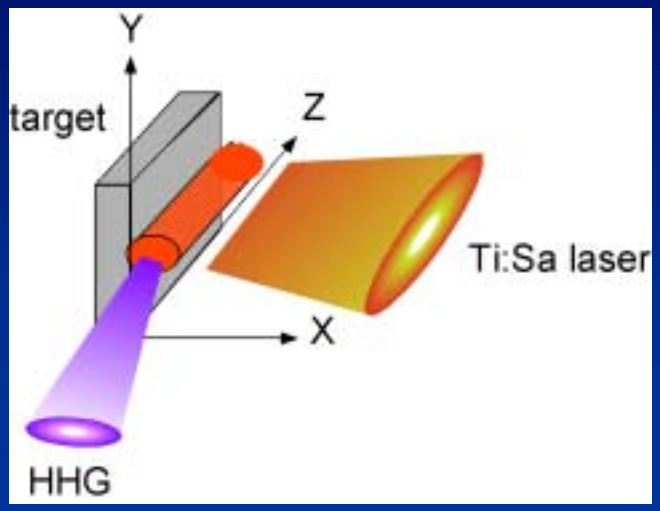
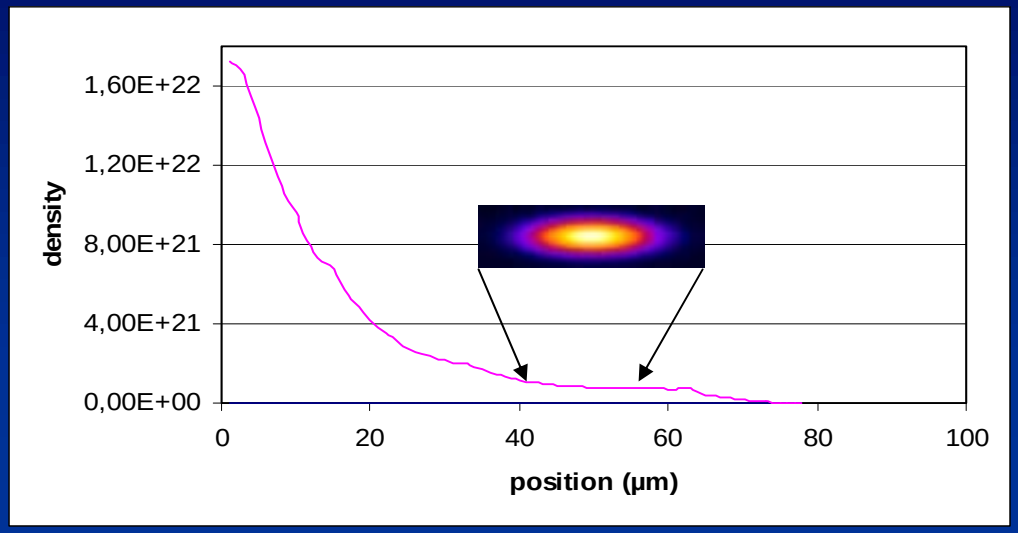
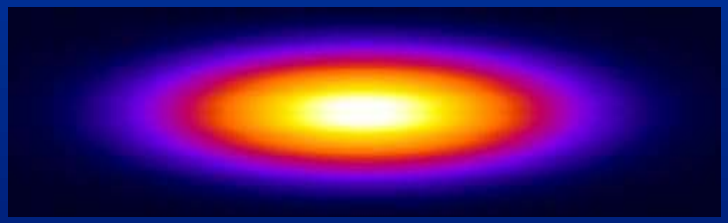
The beam refraction is the major problem



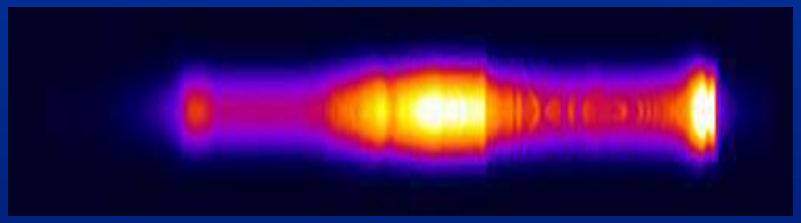


HHG as seeded



1 mm

HHG after propagation in a real plasma



Expected seeded XUV laser parameters :

1mJ, 50 fs, diffraction-limited, 0.1 to 10 Hz, $\lambda \sim$ 1- 4 nm

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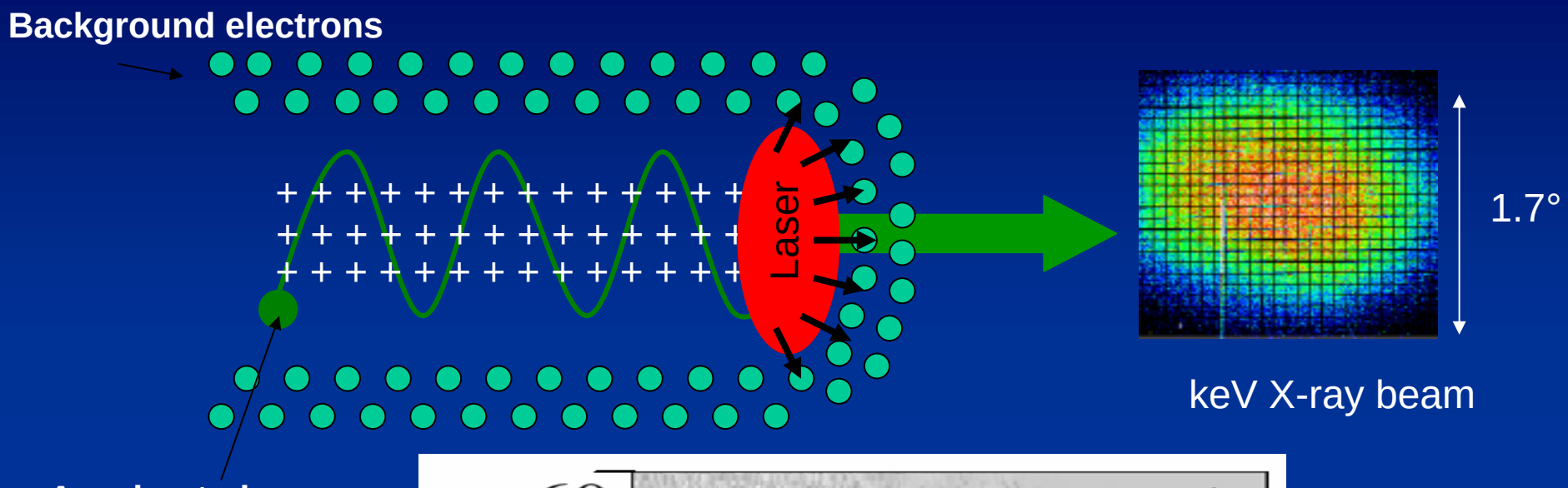
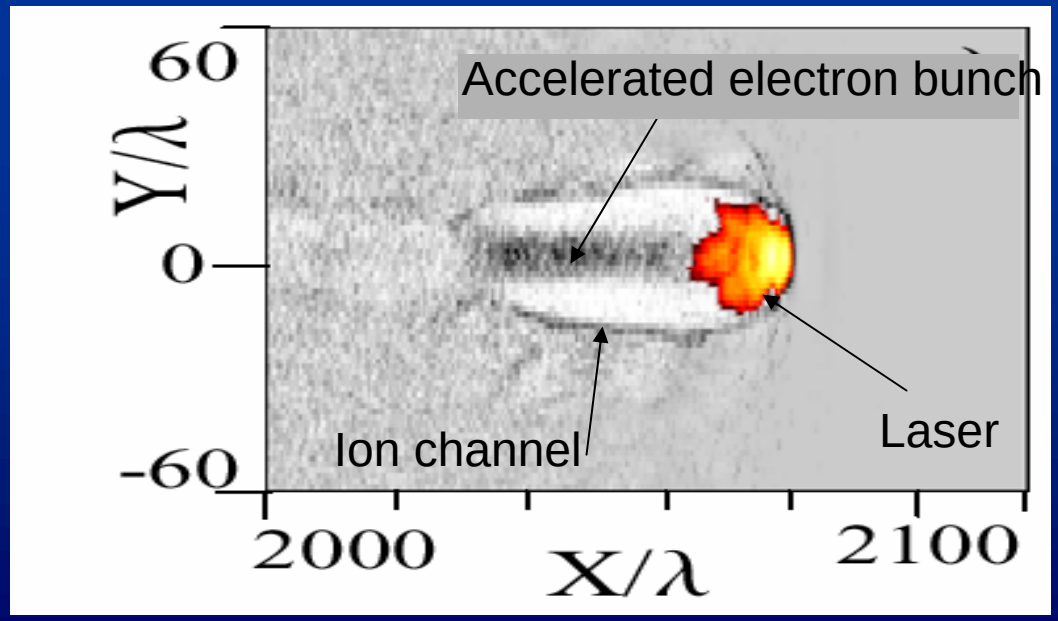
Plasma wiggler : an intense, table-top source of X-rays

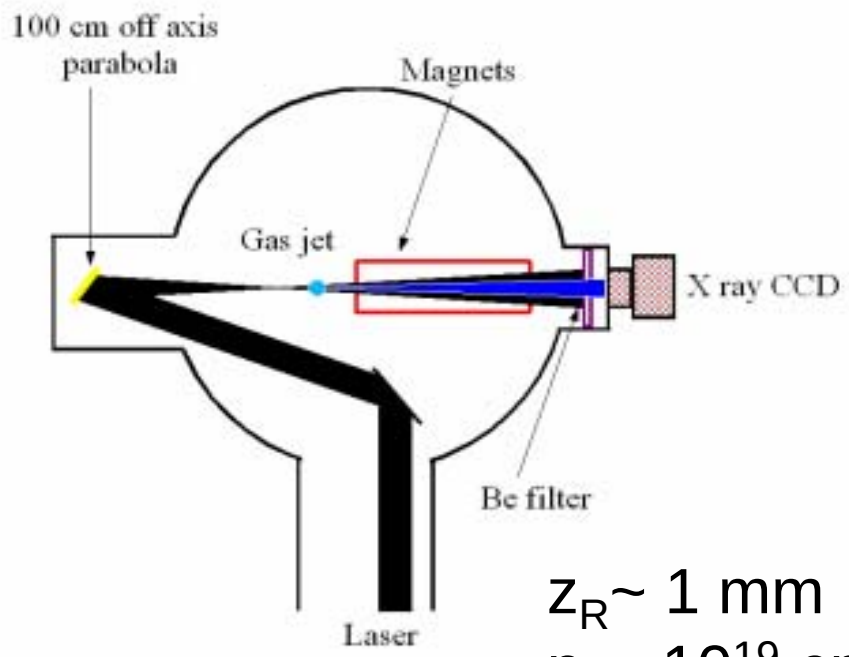


3D simulation of the electron density



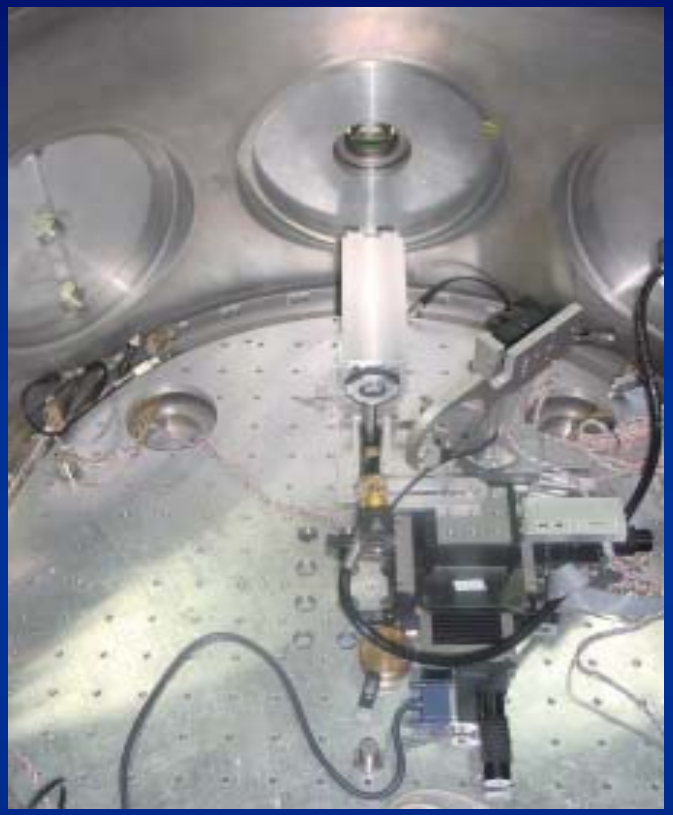
A. Rousse et al, Phys. Rev. Lett. in press (sept. 2004); J. Faure et al, Nature, in press.

A simple and promising technique



$z_R \sim 1$ mm

$n_e \sim 10^{19}$ cm^{-3}



Today :

100 TW laser

Electron E ~ 60 MeV

10^7ph/pulse/0.1%BW

Ephoton~1 keV

20 mrad

Today + 3 years:

200 TW laser => PW laser (O.1 Hz)

E ~ 150 MeV => >300 MeV

10^7ph/pulse/0.1%BW

E photon ~15 keV => $\geq$ 50 keV

1 mrad

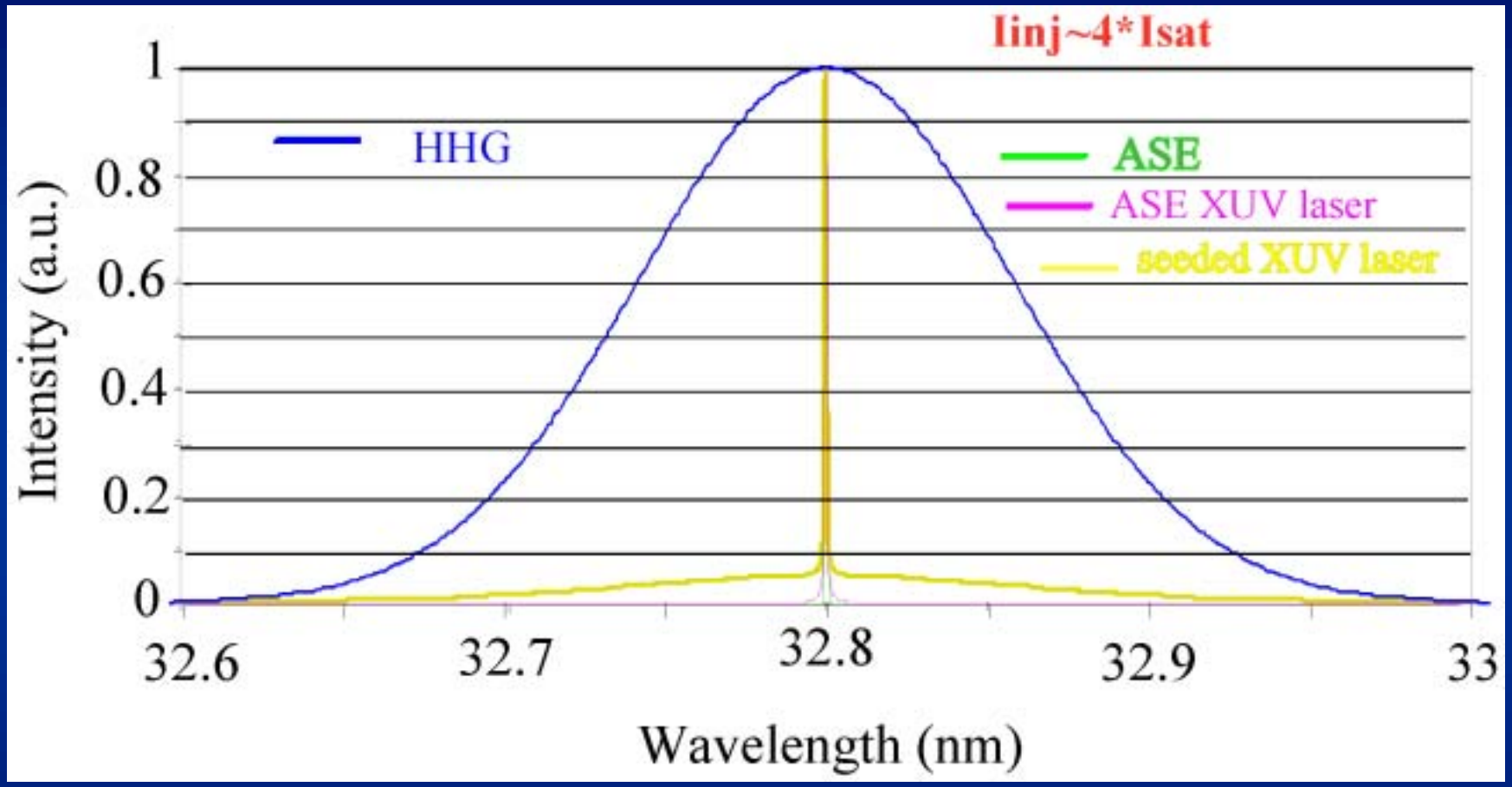
Conclusion : A bright, short (pulse) futur

- As it High harmonics might be used for many test-bed experiments prior going to a VUV -FEL

- Seeded soft x-ray laser has reached 1 μJ, 500 fs, Diffraction-limited
  - To + 6 months : 30 μJ, 500 fs, Diffraction-limited, @ 30 nm
  - To + 2 years : Real XUV amplifying chain with solid amplifier 1 mJ, 50 fs, DL @ 30 nm => focused intensity ~ 10^{19} Wcm^{-2}
  - To + 3 years : 1 mJ, 50 fs, DL @ 13 nm

- Plasma wiggler : 1 keV, 10^7 ph/puls/0.1 %BW
  - To + 2 years : 15 keV, 10^7 ph/pulse/0.1BW, 1 mrad
  - Towards FEL-like source (enhancement of the coherence)

Amplification on line wings.



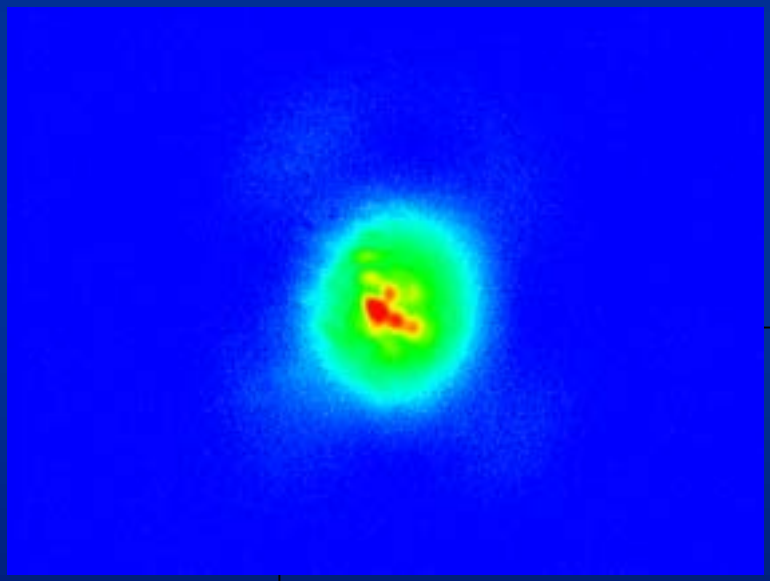
It is possible to extract energy from the wings of the XUV line

$\Delta t = TF(I(\lambda)) \Rightarrow \Delta t = 500$ fs (2.5 ps in ASE)

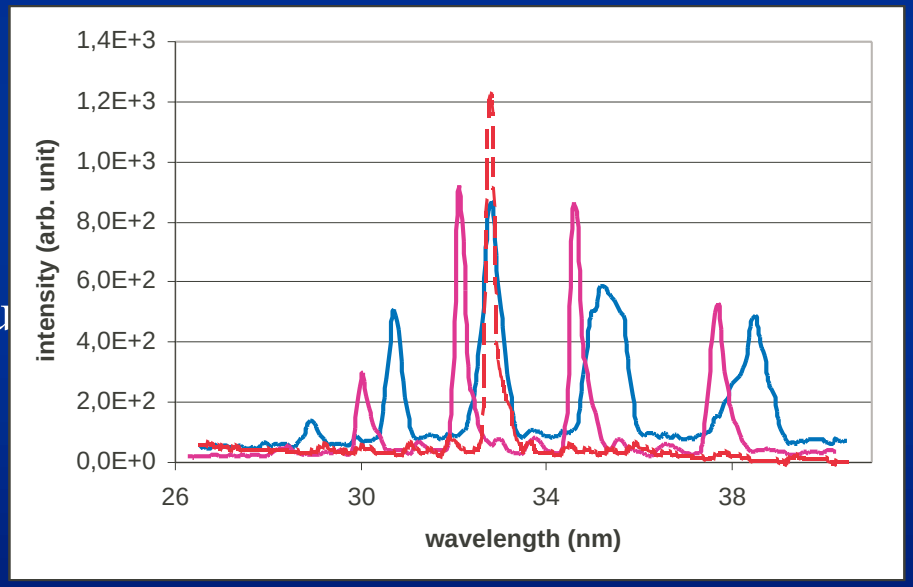
Control of the seeding parameters

1 Spatial superimposition

2 Spectraly tuned by playing with the IR laser



Pu



Both beams
Driving laser of the XUV laser

3 Synchronisation (30 fs accuracy)

Principe du laser X “OFI”

- **Ionisation**

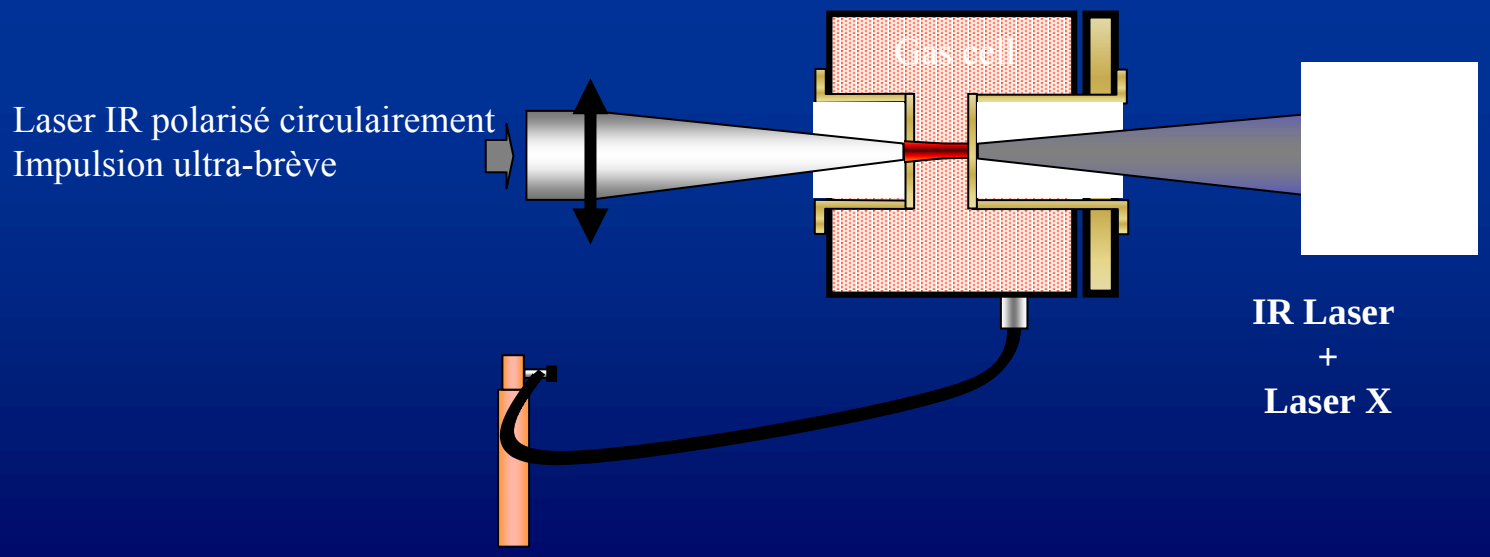
Ionisation tunnel

Xe^{8+} : **I=1.6 *10^{16} W.cm^{-2}**

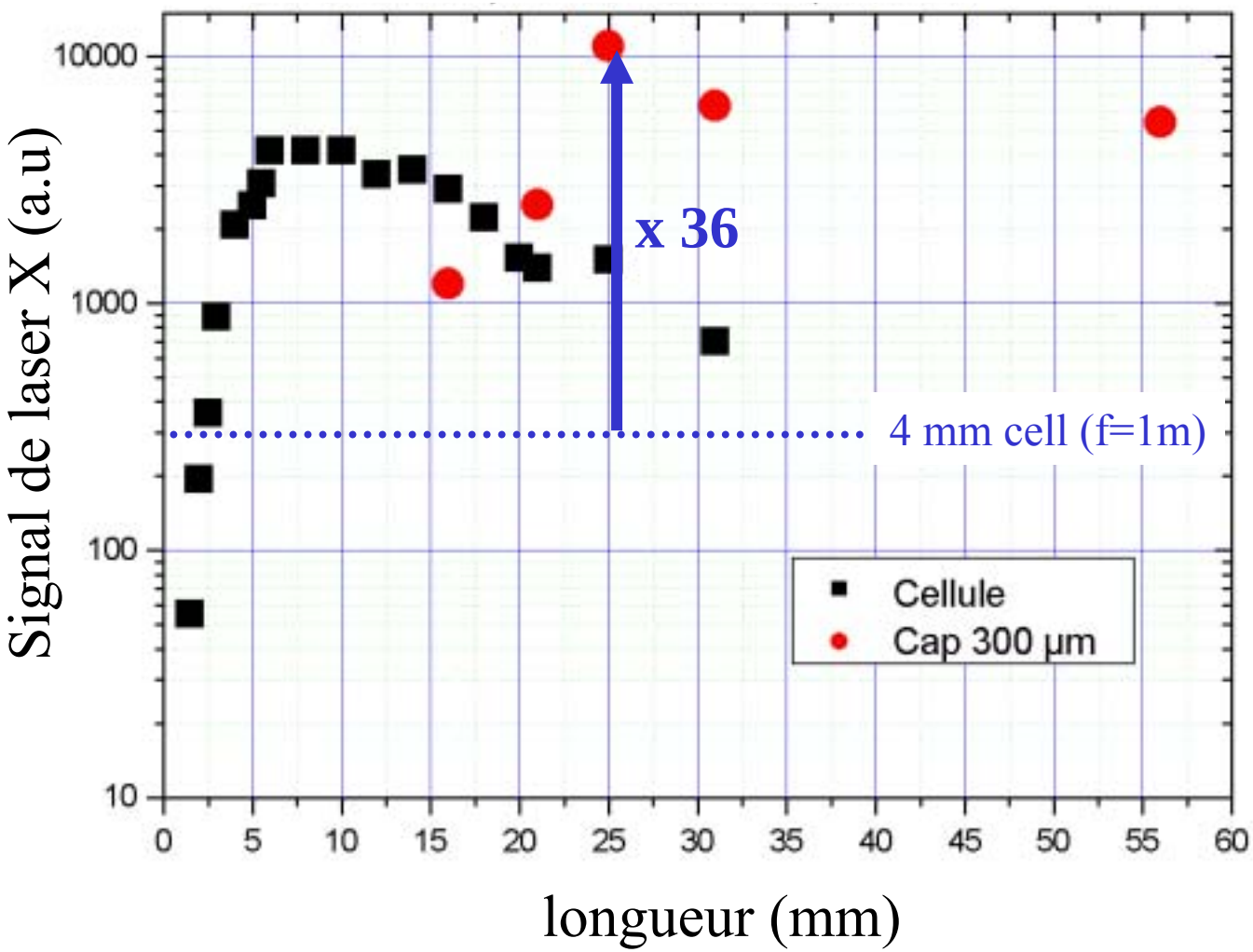
Kr^{8+} : **I=2.3 *10^{16} W.cm^{-2}**

- **Pompage par les électrons chauds**

Polarisation circulaire

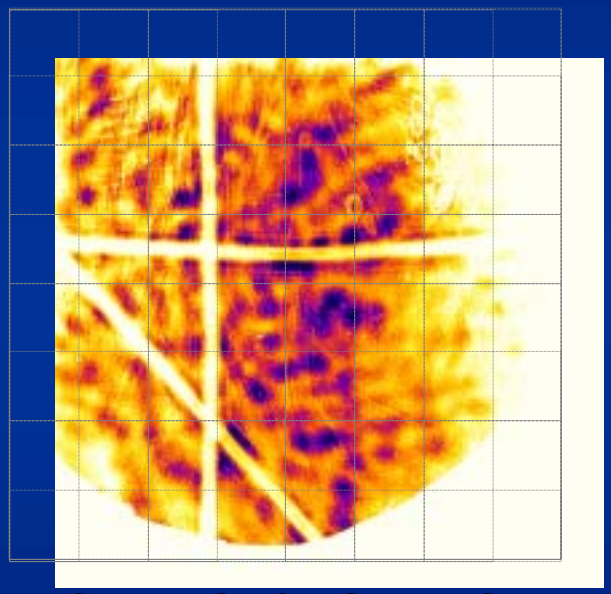


Capilaire + focal de 2 m : *36 sur l'intensité



Far field pattern of the 41.8 nm laser using a 25 mm tube

f=1 m, L_{cell}=4 mm

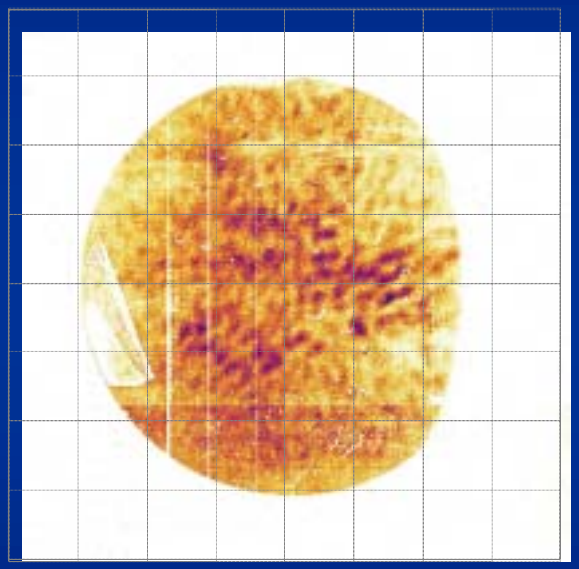


-6 -4 -2 0 2 4 6

(mrad)

Divergence >12 mrad

f=2 m, L_{cell}=8 mm

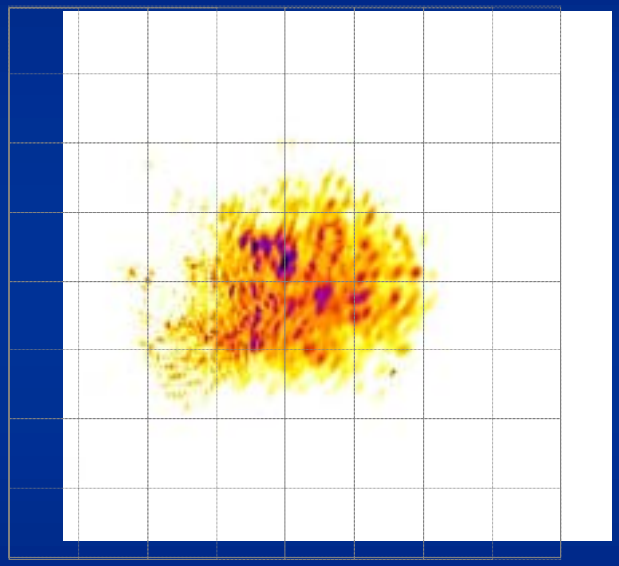


-6 -4 -2 0 2 4 6

(mrad)

Divergence < 8 mrad

f=2 m, L_{cap}=25 mm

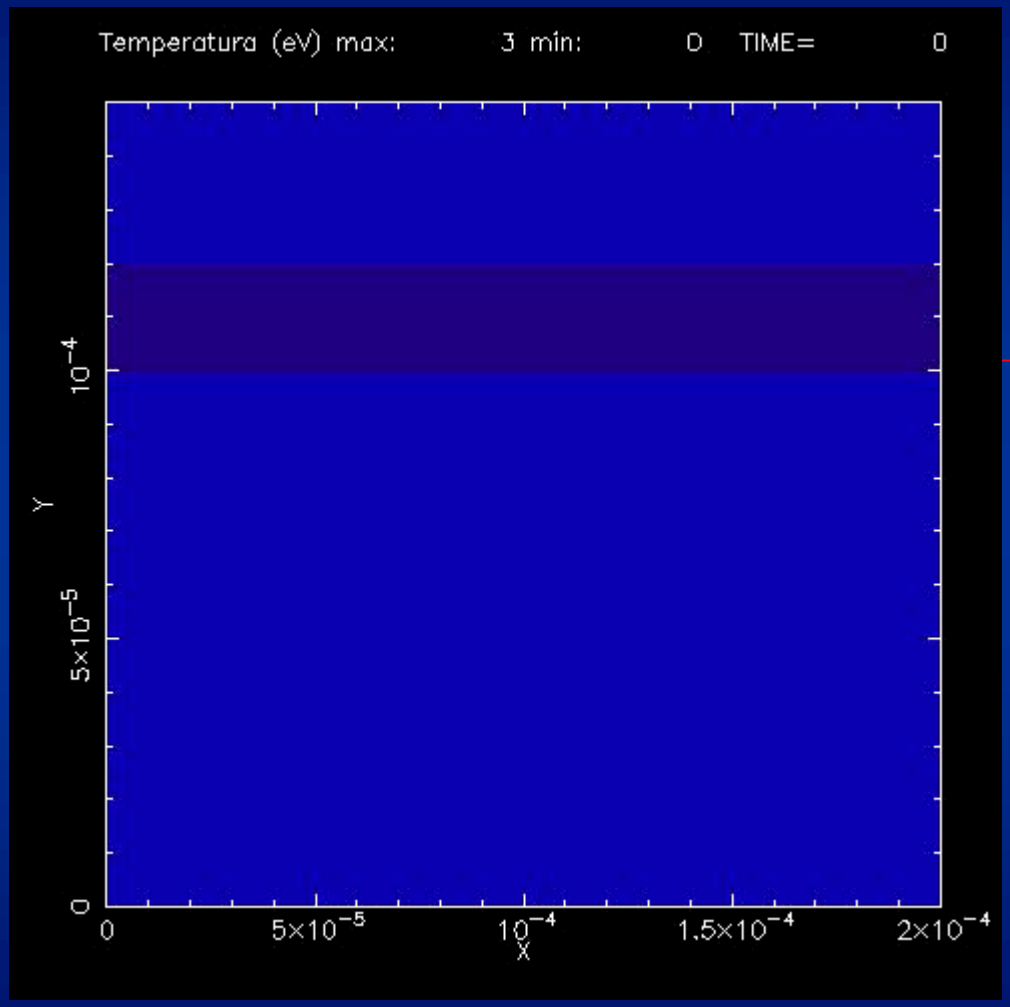


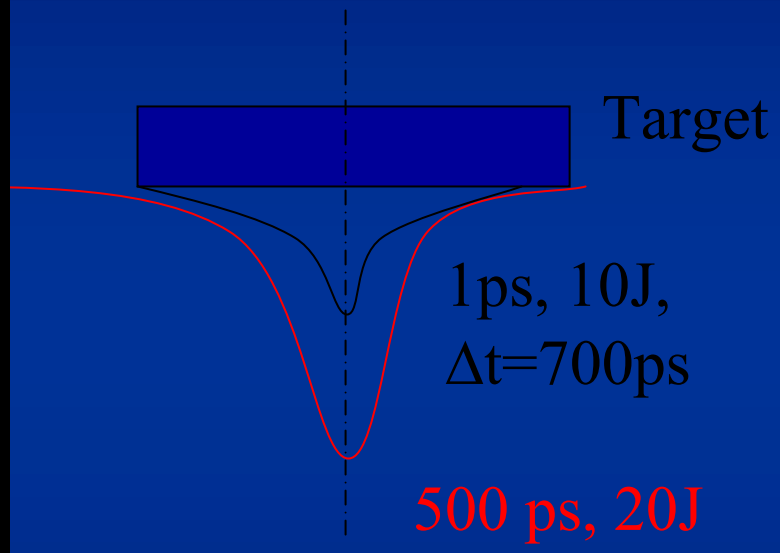
-6 -4 -2 0 2 4 6

(mrad)

Divergence < 4 mrad

2D modelling of a transiently pumped plasma





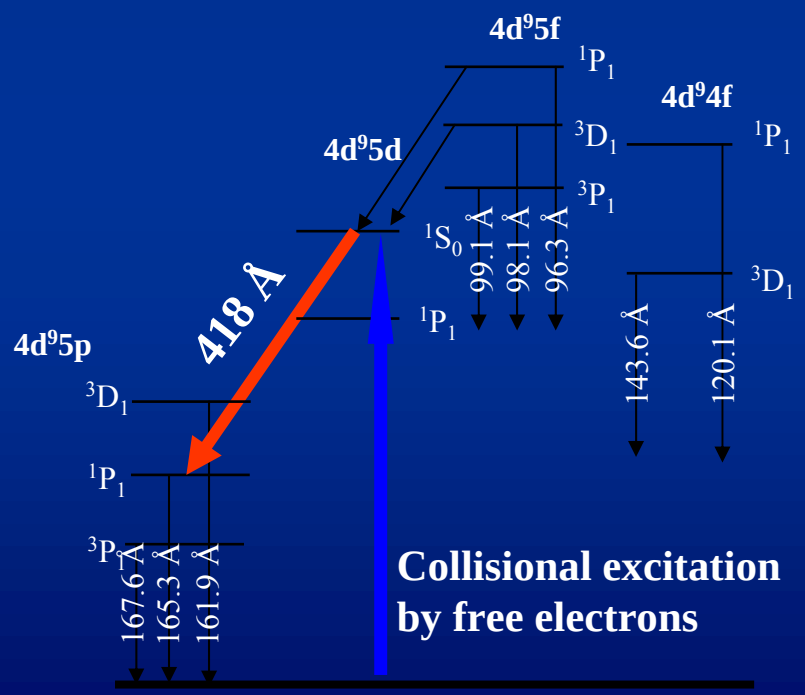
ARWEN code :
2D hydrocode with
Adaptive Mesh Refinment

Collaboration with P. Velarde, F. Ogando, Madrid, Spain

Optical Field Ionisation soft x-ray laser.

Pd-like xenon

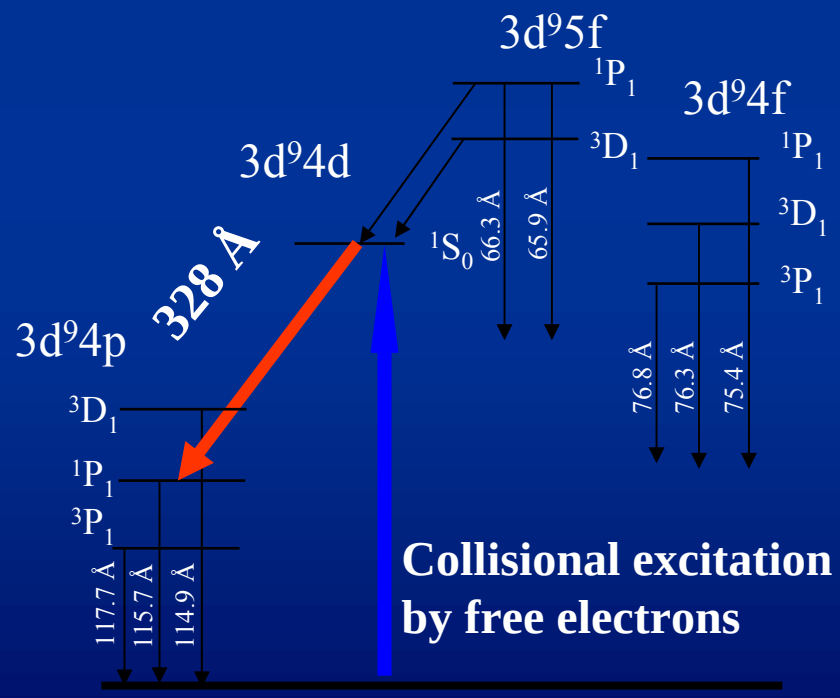
Rh-like ground state ($4d^9$)



Pd-like ground state ($4d^{10}$)

Ni-like krypton

Co-like ground state ($1s^22s^23p^63s^23p^63d^9$)

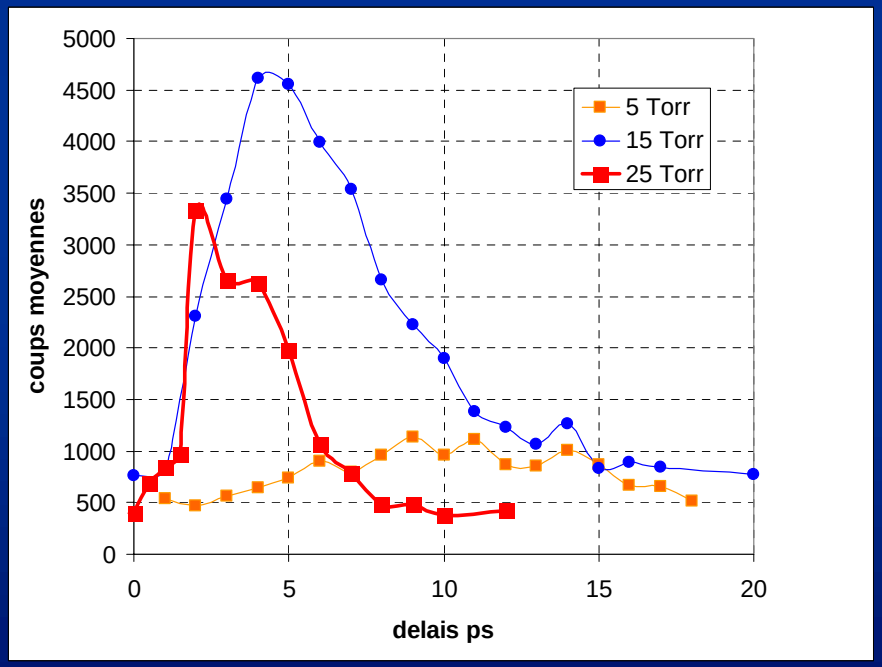


Ni-like ground state ($1s^22s^23p^63s^23p^63d^{10}$)

Mesure DIRECTE de la durée du gain

$I = I_{inj}*(\exp(G*L)-1)$ $G \propto n_{sup} - n_{bas}$ L : longueur

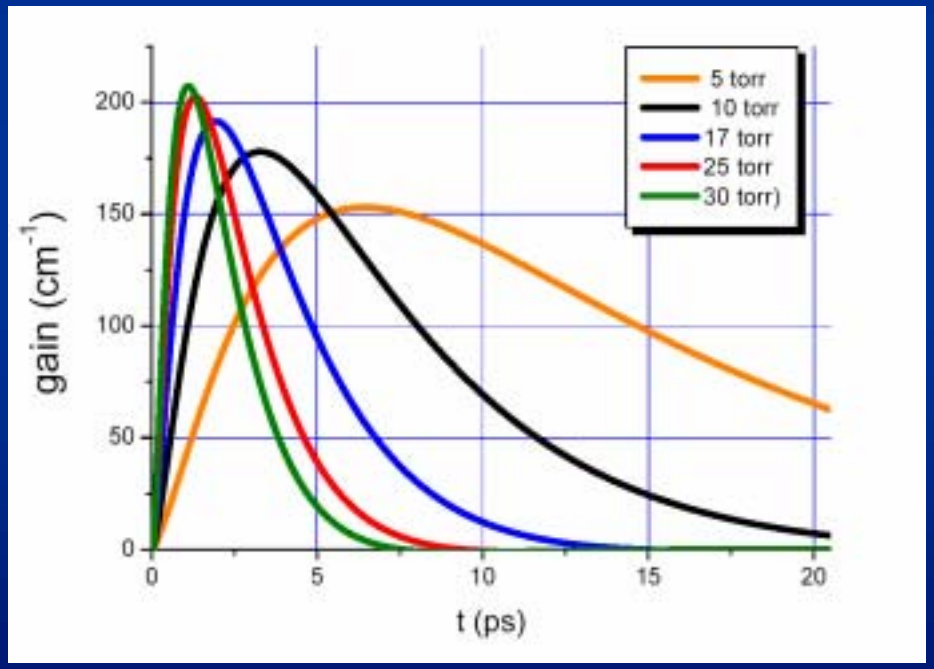
Xe^{8+} (41.6nm, H19)



Gmax => P= 15 torr => Δt =8 ps

modélisation

Kr^{8+} (32.8 nm, H25)



Gmax => P= 25 torr => Δt =4 ps

Modélisation effectuée par G. Maynard (LPGP) + J. Dubau (LIXAM)