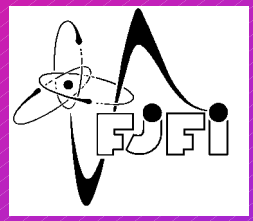
Pulse Plasma Systems – Modeling and Measurements, Prague October 2001



Experimental and Theoretical Study of Transient X-ray Lasers: First Step Towards Interferometrical Applications

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Scheme of an X-ray laser

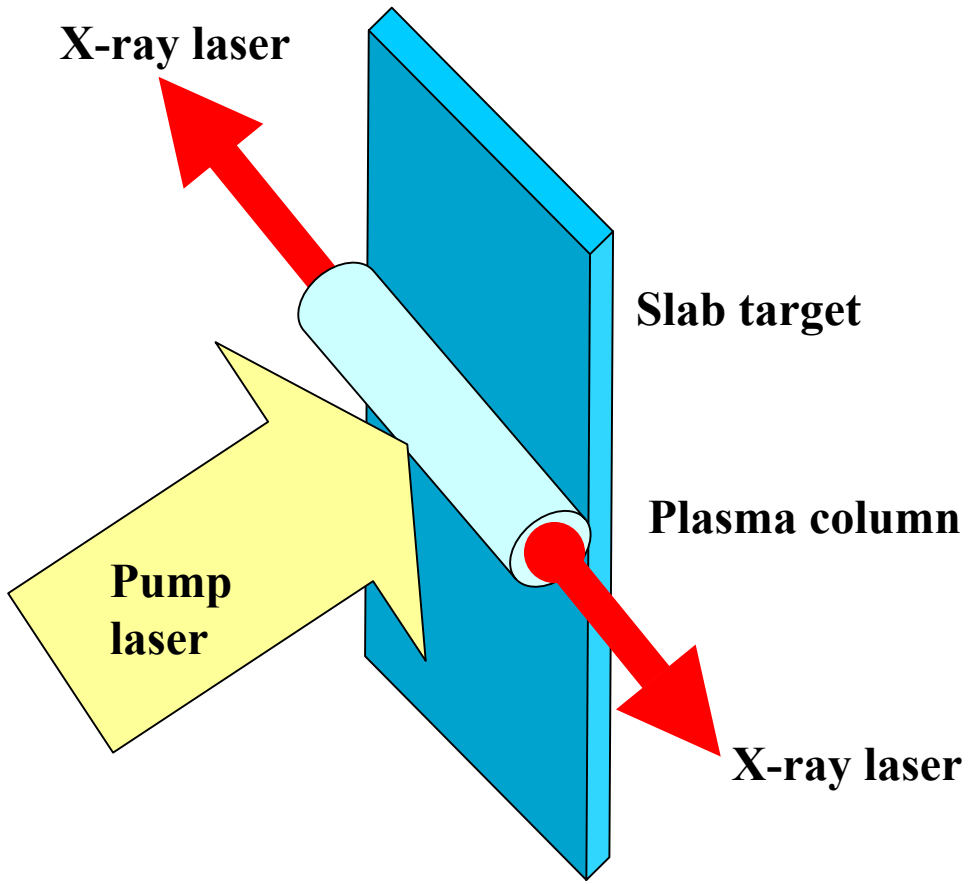
(X-ray laser pumped by a laser)

- Target evaporation
- Ionisation
- Creation of a population inversion

The plasma is heated by

♣ the same (standard «quasi-steady-state pumping ») or

♣ by another laser pulse («sequentiel pumping» and «transient pumping»)



Transient Pumping

Goal: **To reduce the pump laser energy**

Increase the repetition rate

$\Big\} \Rightarrow$ table-top X-ray laser

→ **A new method: Transient pumping**

Transient Pumping

Two pump pulses:

„long“ ~ 3 J/cm, ~ 1 ns (~10^{12} W/cm^2)

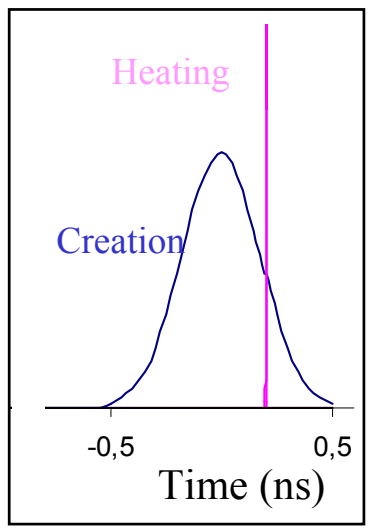
„short“ ~ 5 J/cm ~ 1 ps (~10^{15} W/cm^2)

Delay between the two pulses ~200 ps

X

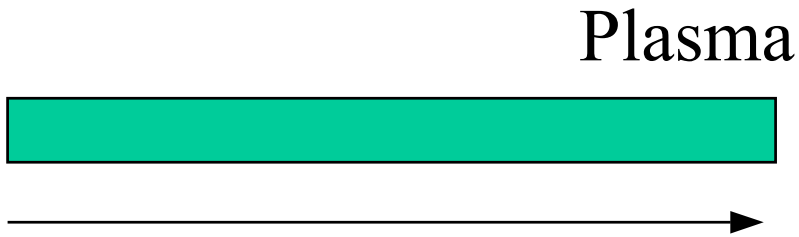
« Standard » Pumping

hundreds of Joules in one pulse



The gain is high, but lasts for a short time only

Transient Pumping



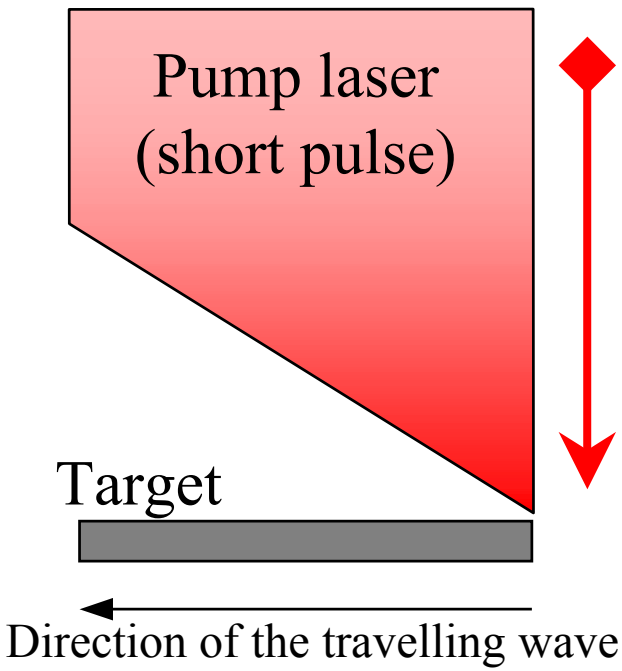
But: gain duration < 10 ps

→ The photons are amplified during a small part of their transit through the plasma column, only.

How can we solve this problem ?

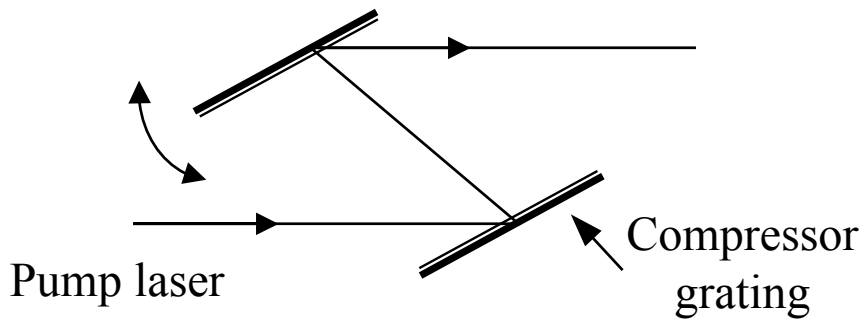
Transient Pumping

Solution: A travelling wave - «guillotine principle»



How to create a travelling wave?

For example, by tilting the second grating of the pulse compressor (« LULI method »)



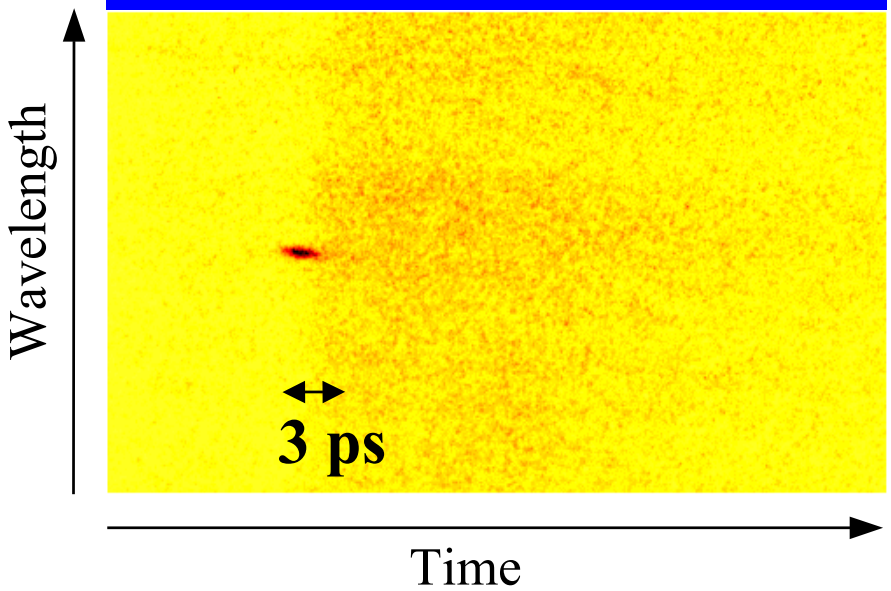
This method allows to control exactly the speed of the travelling wave

Rutherford 2000 Experiment

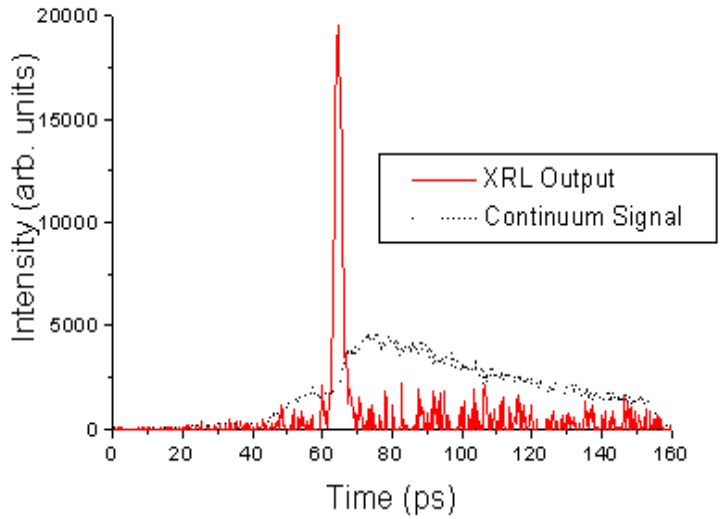
Duration of a Transient X-Ray Laser

Very short X-Ray Laser Emission in the Optimal Conditions

CCD image from the streak camera



Temporal history at 13.9 nm



Ni-like Ag X-ray laser at 13.9 nm

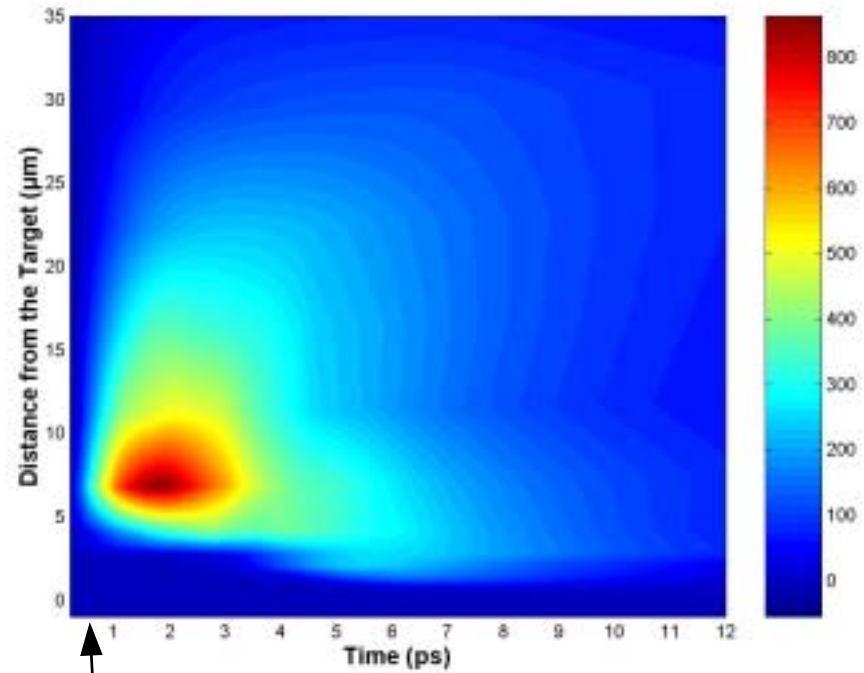
The duration of the XRL pulse at 13.9 nm was measured (after deconvolution) to be (1.8 ± 0.7) ps

Time-resolved Study: Summary

- The shortest X-ray laser pulse to-date was demonstrated: (1.8± 0.7) ps (new perspectives for applications)
- The x-ray laser pulse appears in the rising edge of the continuum emission

Numerical Simulations by EHYBRID code

EHYBRID (developed by G. J. Pert at York University) is one of numerical codes that interconnect atomic physics and hydrodynamics. The code enables to model X-ray lasers, Ne-like or Ni-like, pumped by a laser pulse.



Pump laser pulse maximum

Rutherford 2000 experimental conditions

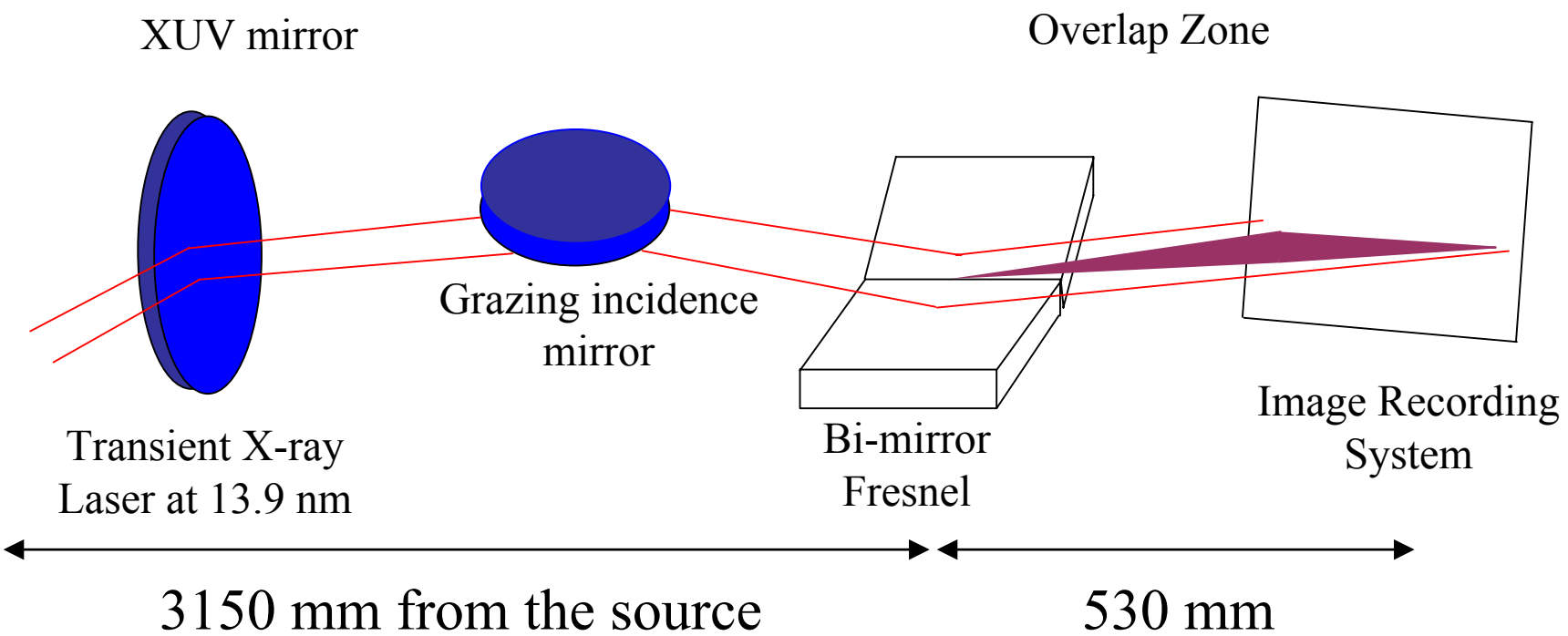
- Maximum (local) gain 863 cm^{-1}
- Electron density 4.6 x 10^{20} cm^{-3}
- Electron temperature 1472 eV

The gain duration of 3.1 ps is predicted, which is consistent with measured XRL pulse.

Numerical Simulations of RAL experiment: Summary

- Very high local gain are calculated by numerical simulation (raytracing calculation required)
- The gain duration of 3.1 ps is predicted by the numerical simulation (consistent with the measured XRL duration)
- The simulation of the Bremsstrahlung confirms and explains that the x-ray laser appears before the peak of continuum emission

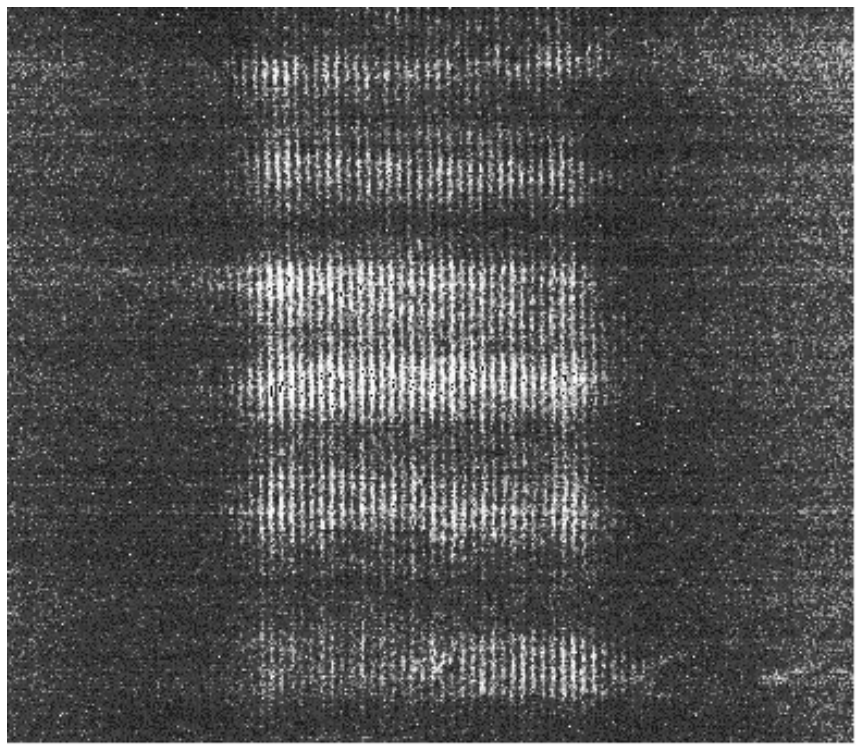
The first interferogram by a transient X-ray laser: Fresnel bi-mirror inteferometer



F. Albert et al.: Phys. Rev. B **60** 11089 (1999)

QSS laser at 21.2 nm, deformation of Nb surfaces

The first interferogram by a transient X-ray laser



Ni-like silver X-ray laser

Travelling wave: c

Target length: 10 mm

The fringe visibility of ~50 % is observed even though the signal is very weak over the background.

Conclusion

Characteristics of the transient X-ray laser

Wavelength	13.9 nm
X-ray laser energy	~3 μJ
Pulse duration	~2 ps
Power	1.5 MW
Horizontal divergence (Limeil experiment)	3 mrad
Deflection angle (Limeil experiment)	9-10 mrad
(RAL experiment)	5-6 mrad

Some Perspectives

A transient X-ray laser with small energy requirements and very short pulse duration opens new perspectives for many applications.

- Transient deformation of perturbed surfaces
- Probing of dense plasmas (ICF)
- Non-linear interaction with matter
- …

→ Project of an X-ray laser facility POLA-U3M