EXTREME LIGHT INFRASTRUCTURE

- un nou impuls pentru cercetarea stiintifica interdisciplinara -

Magurele 17-18 Septembrie 2008

Generare de pulsuri multiple in sisteme laser ultrarapide si aplicatii la laserul cu raze X

Presented by Daniel Ursescu

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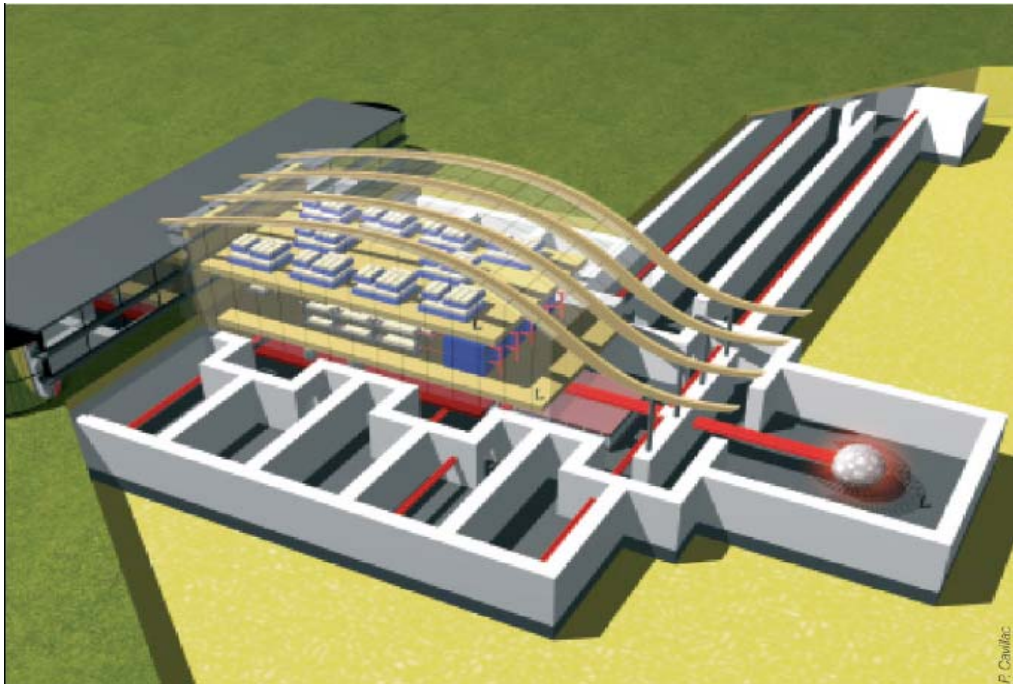
Contents

- Extreme Light Infrastructure and Chirped pulse amplification
- Multiple pulses generation
- Applications to X-Ray Lasers

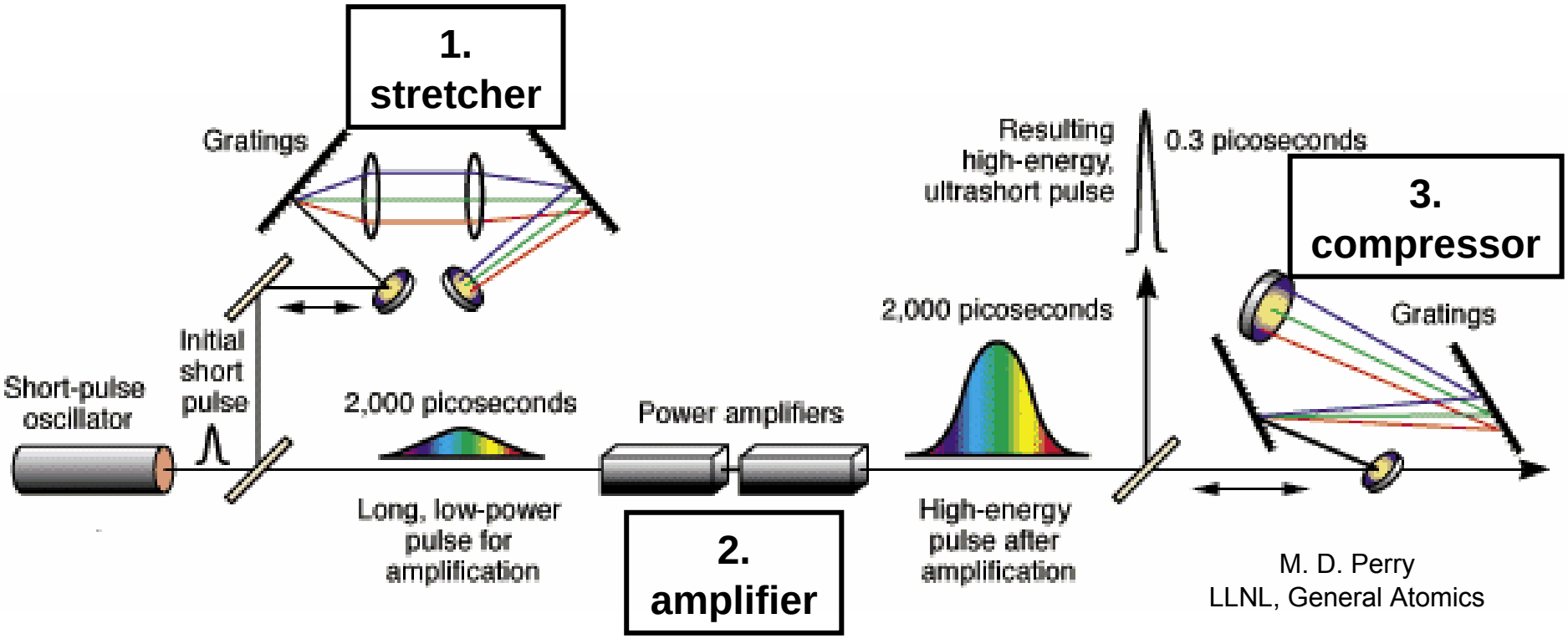
EXTREME LIGHT INFRASTRUCTURE

ELI will be the first pan-European large-scale facility dedicated to multi-disciplinary applications



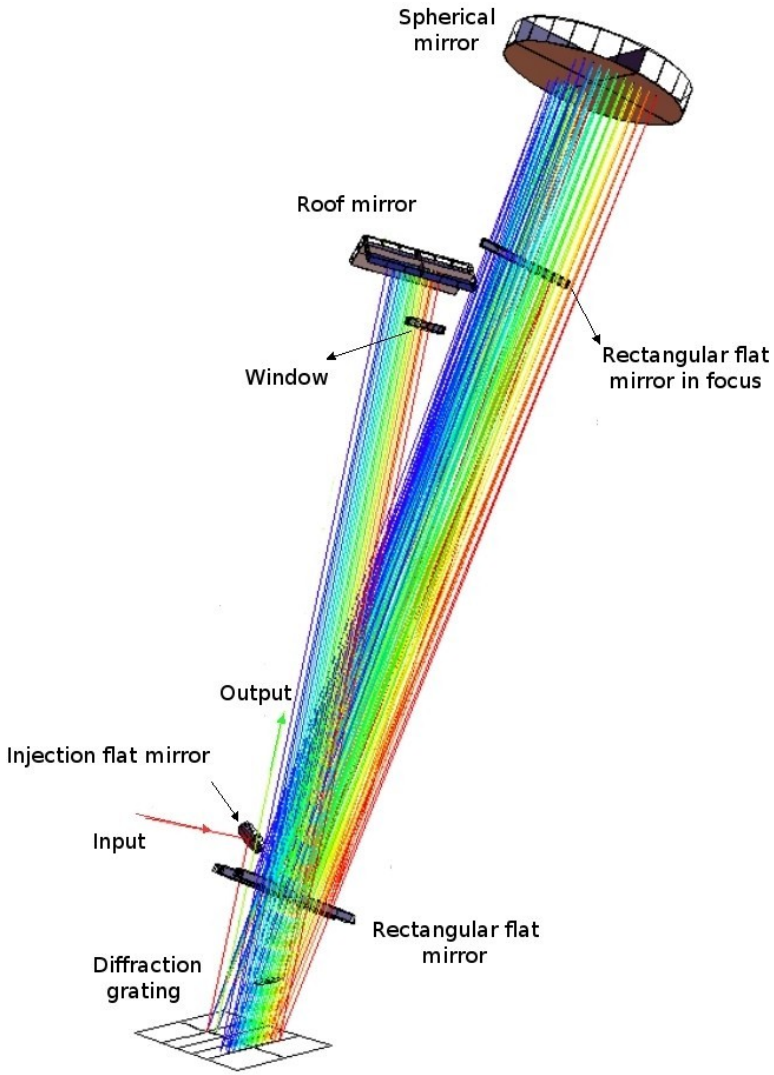
ELI would afford wide benefits to society ranging from improvement of oncology treatment, medical imaging, fast electronics and our understanding of aging nuclear reactor materials to development of new methods of nuclear waste processing.

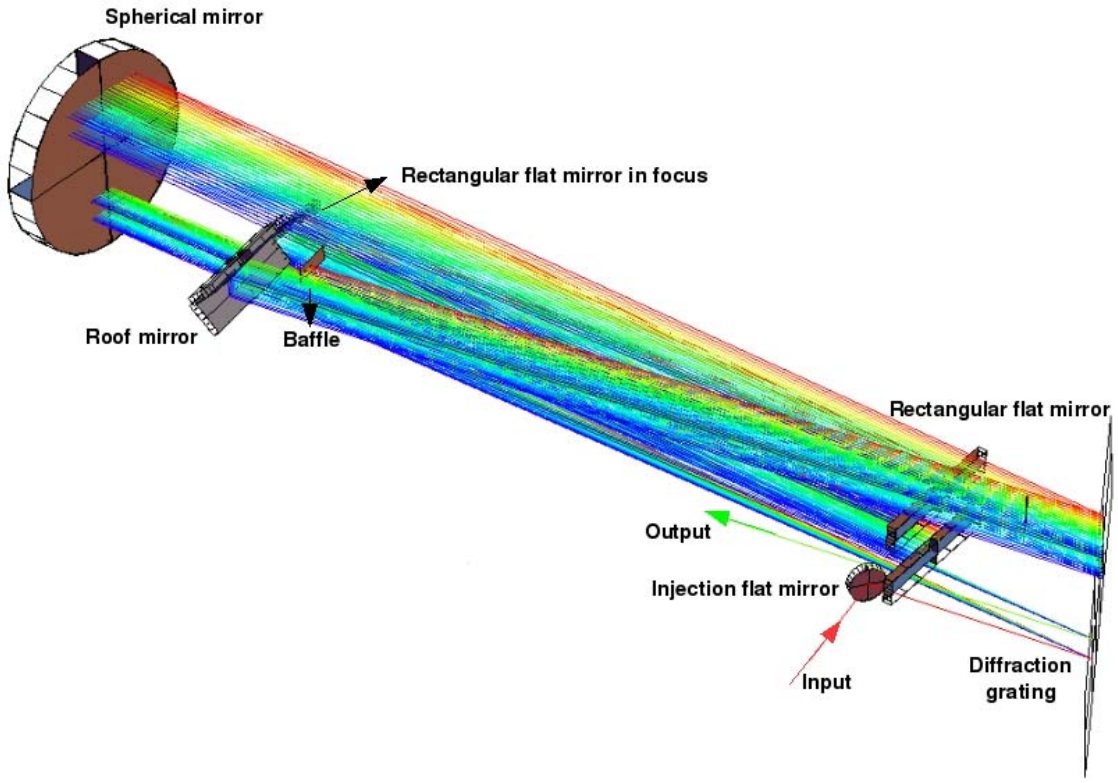
CPA (Chirped Pulse Amplification) to obtain 10^{15} W



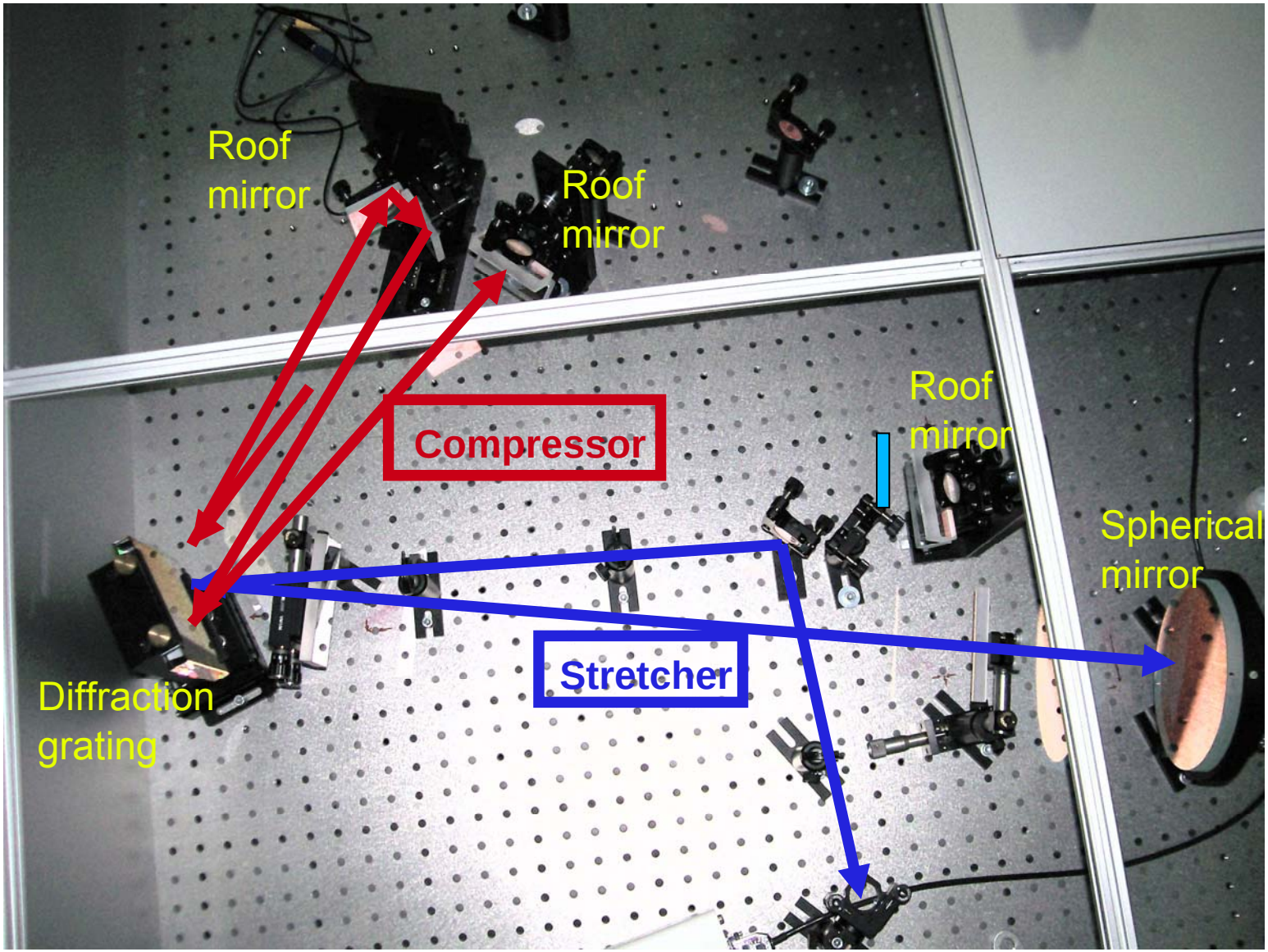
- **A broad band width fs-pulse is stretched by a parallel grating pair**
- **The stretched ns-pulse is amplified to about 100 J**
- **The high-energy pulse is re-compressed in a grating compressor to 10^{15} W**

3D Stretcher design using ray-tracing

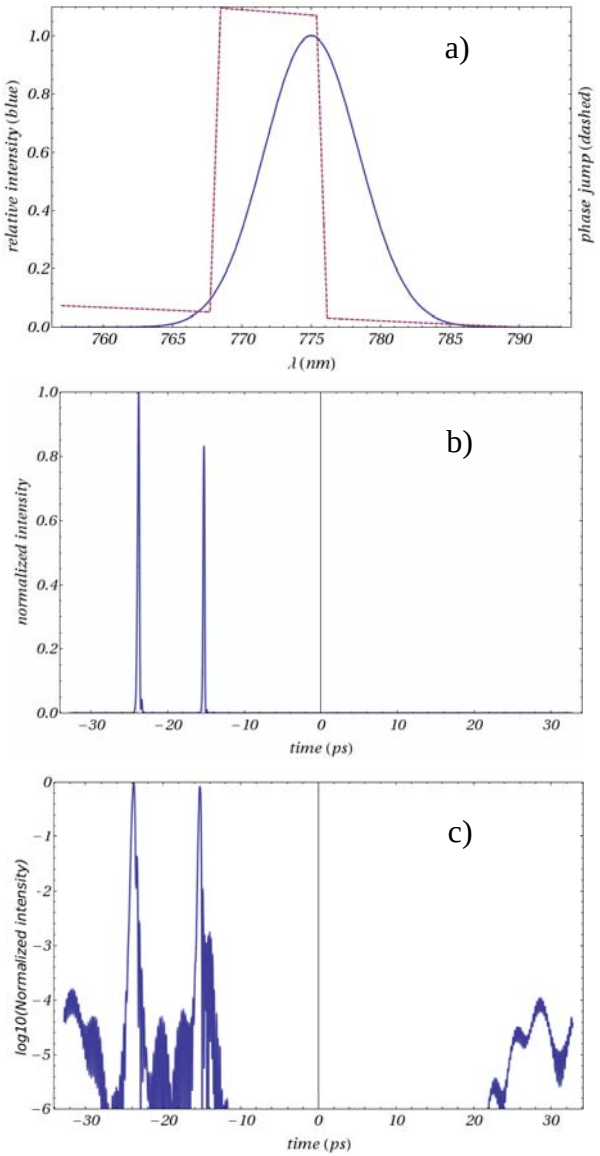




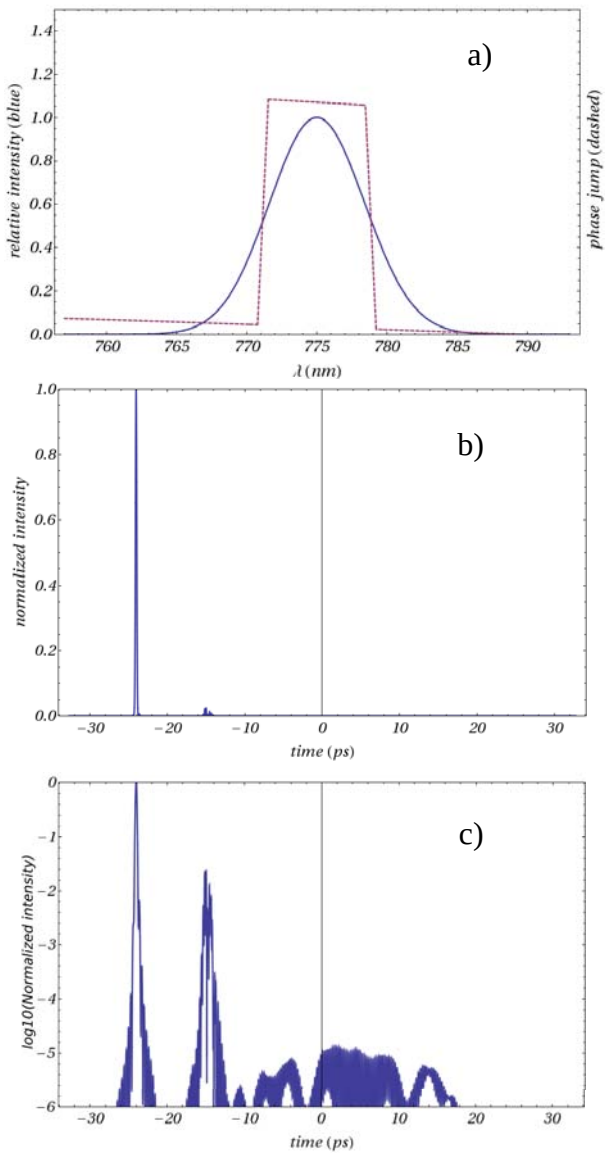
In stretcher pulse shaping



Multiple pulses generation using a window in the stretcher

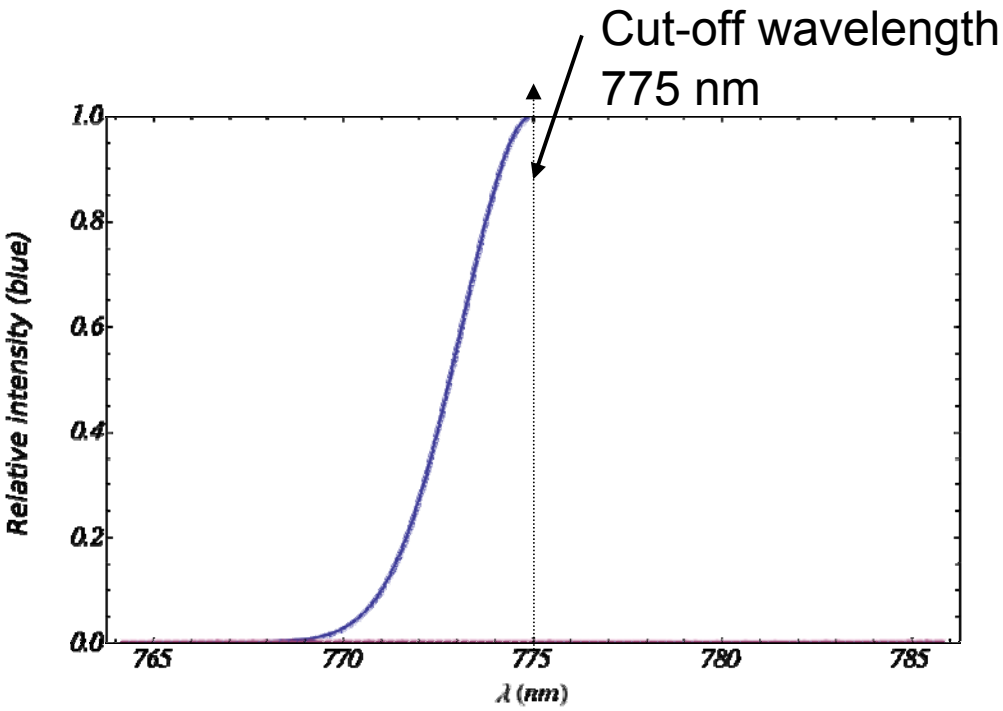


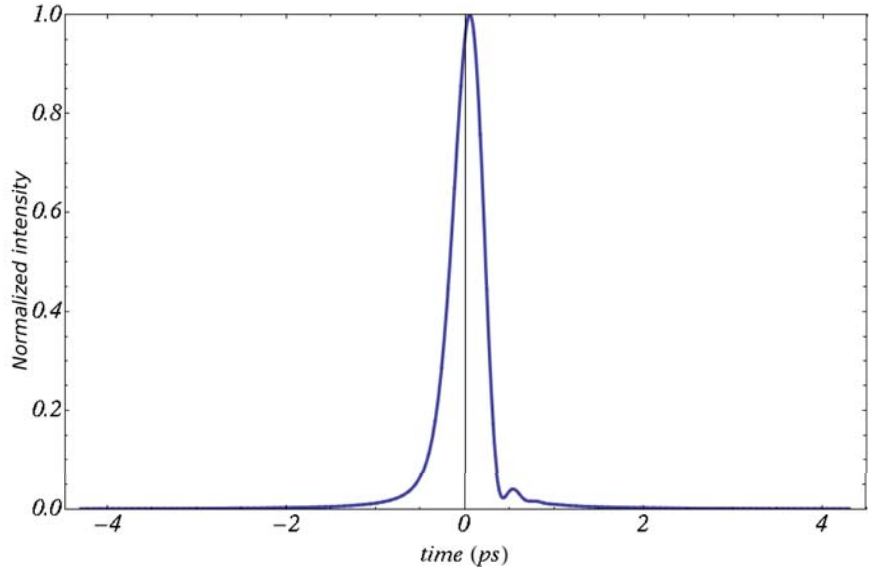
a) Spectrum of the short pulse and phase shift introduced by the window shifted with 4mm from the spectral origin; b) normalized time-dependent intensity of the corresponding pulse; c) contrast evaluation at best compression in a 60 ps temporal window: on the vertical axis is represented the logarithm of the intensity

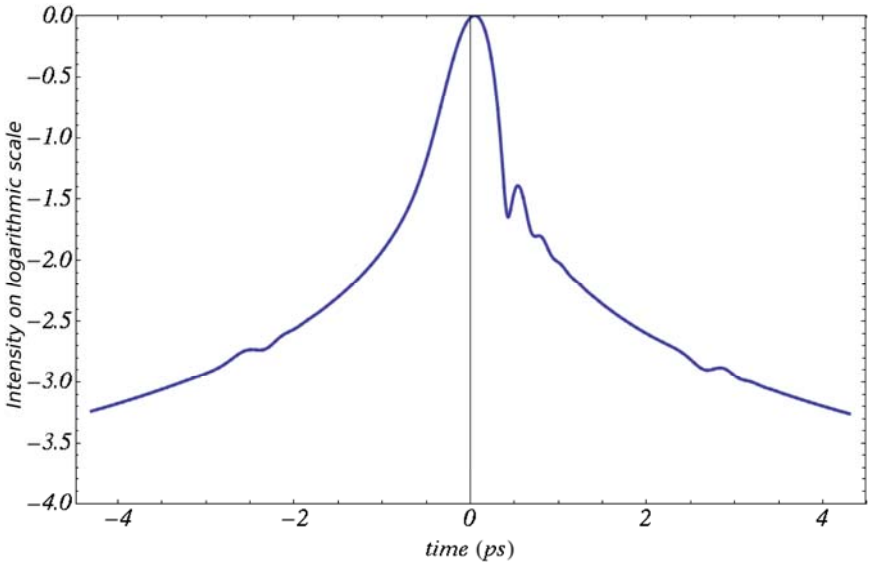


a) Spectrum of the short pulse and phase shift introduced by the window placed at the spectral origin; b) normalized time-dependent intensity of the corresponding pulse; c) contrast evaluation at best compression in a 60 ps temporal window: on the vertical axis is represented the logarithm of the intensity

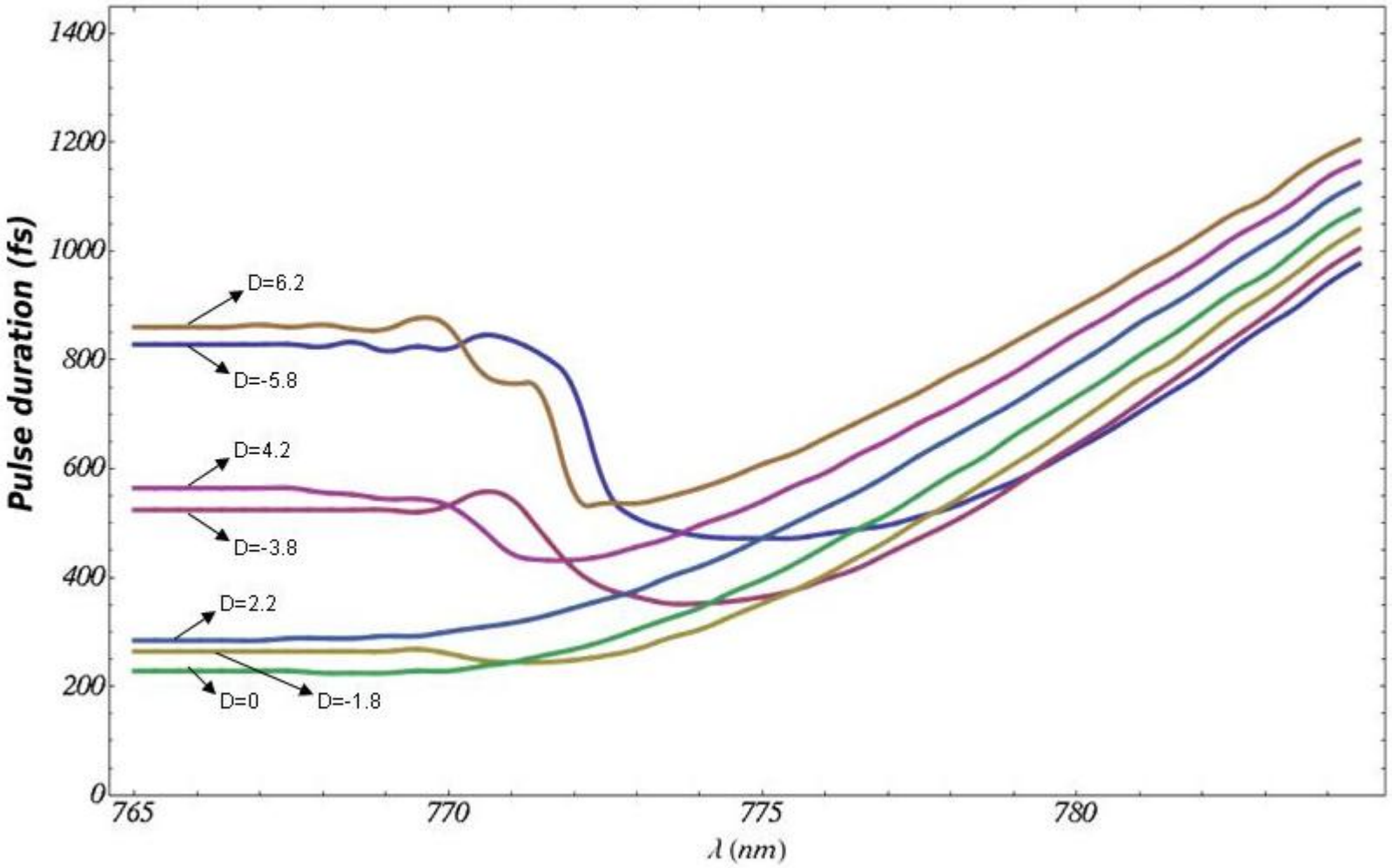
Analysis of the pulse shape





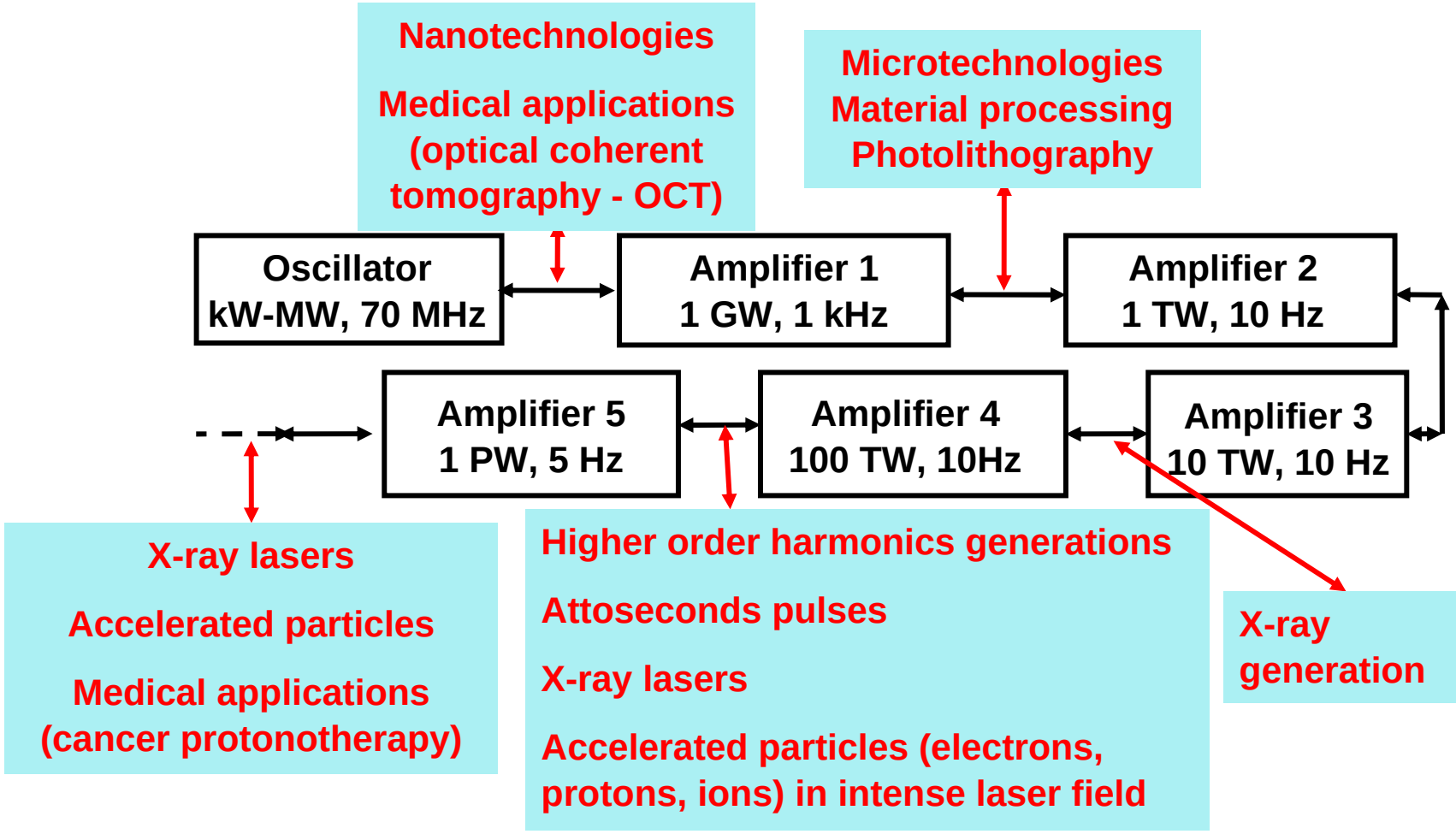


Analysis of the duration of the pulses



The pulse duration as a function of the cut-off wavelengths, for different compressor lengths

Applications of ultraintense femtosecond lasers



Example: 1992: First (and only) Microscopy Experiment using 4.4 nm wavelength laser

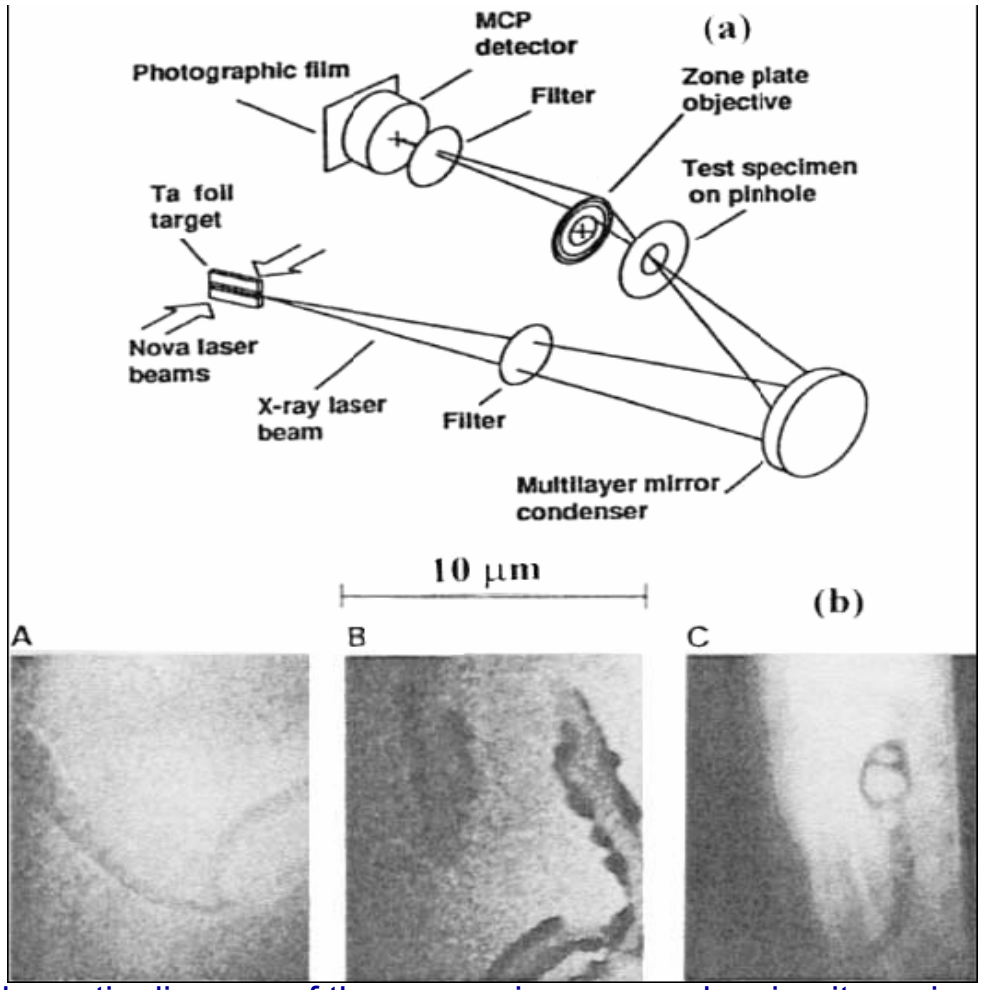
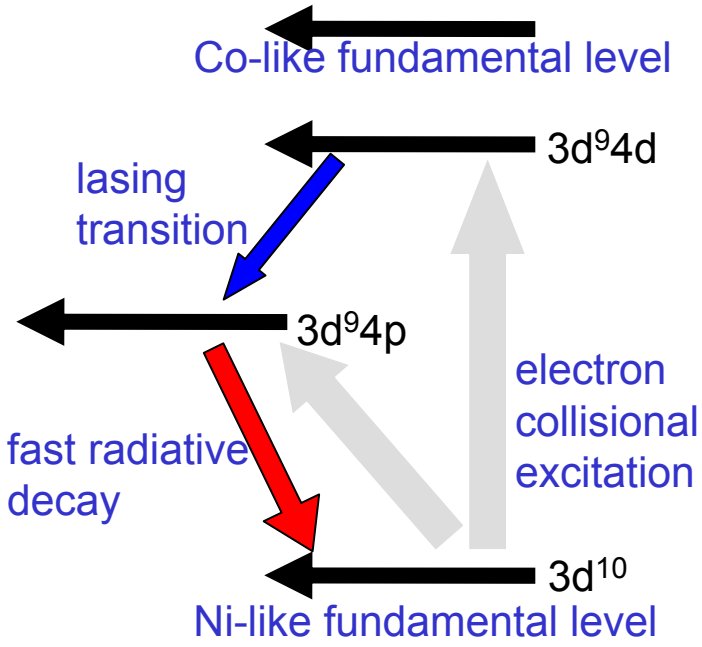


Figure 67. (*a*) Schematic diagram of the x-ray microscope showing its main components. MCP stands for micro channel plate. (*b*) X-ray microscope images of rat sperm nuclei (*a*) with no gold labelling, (*b*) strained with antiprotamine 1 and gold-labelled, and (*c*) strained with antiprotamine 2 and gold-labelled (Da Silva L B et al., 1992 *Science* **258** 269)

Generation of gain by collisional excitation in Ni-like systems

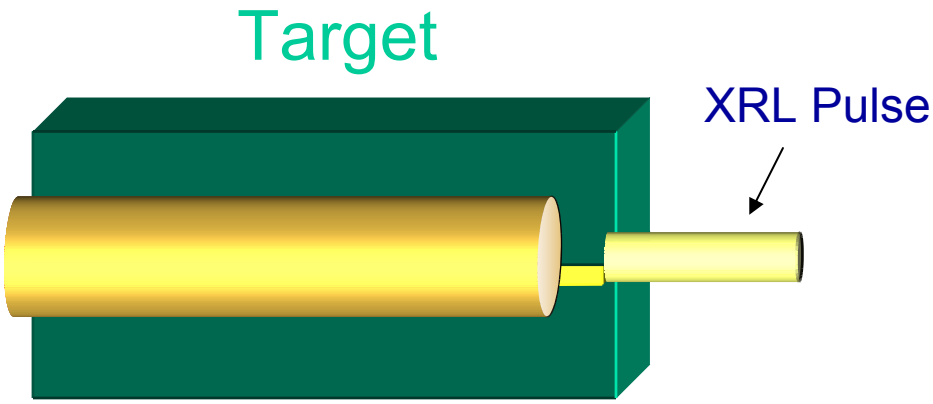


Flavours of X-Ray Laser: **Q**uasi **S**teady **S**tate

QSS: 30 J-10 kJ
0.5 ns

Long prepulse

Long main pulse

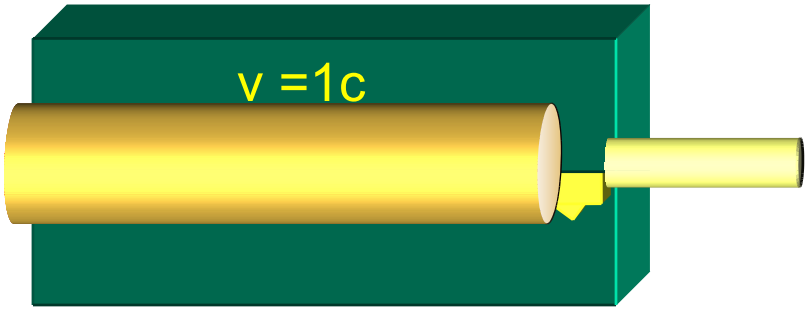


Single pulse: brute force approach

Two pulses: control of the ablated mass

Flavours of X-Ray Laser: **T**ransient **C**ollisionally **E**xcited

Y.V. Afanas'ev and V.N. Shlyaptsev,
Sov. J. Quant. El. **19**, 1606 (1989)
P.V. Nickles et al., PRL **78**, 2748 (1997)



Main pulse: ps
TCE: 3-40 J
46nm – 7.3 nm

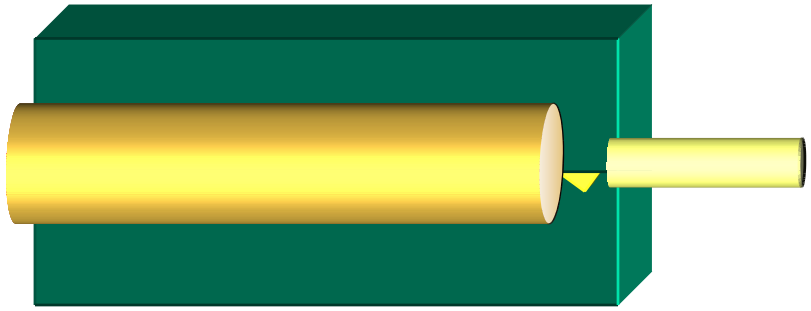
Short pulse: strong collisional excitation

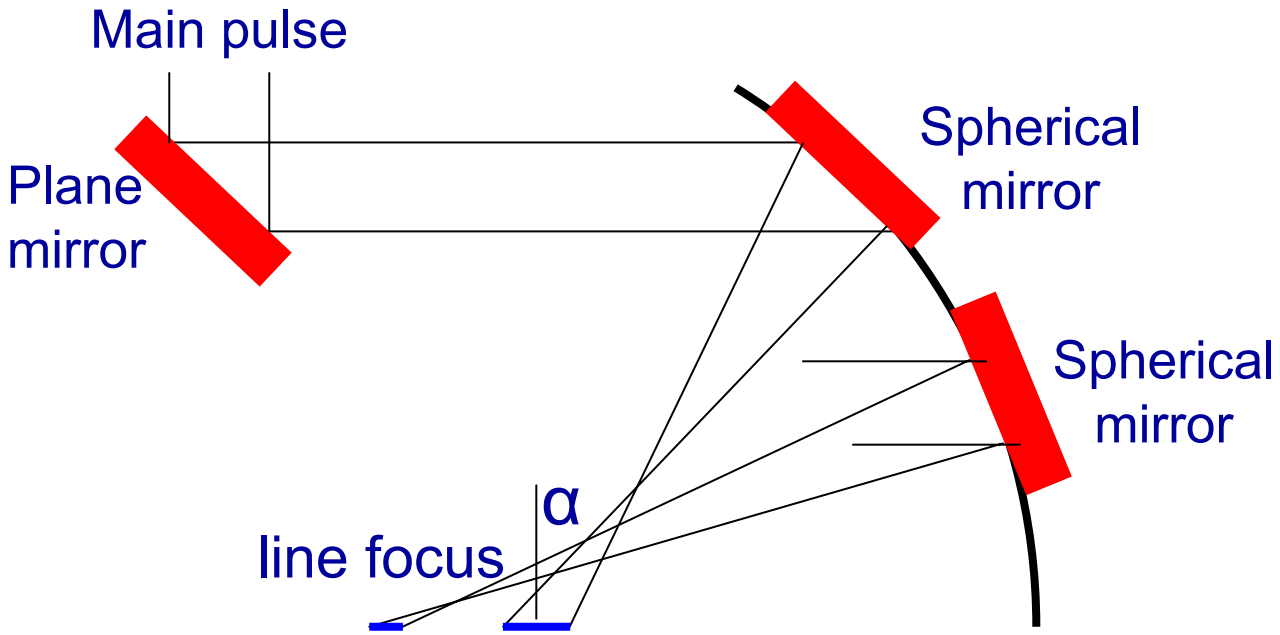
Flavours of X-Ray Laser: **TCE GR**azing **I**ncidence **P**umped

Keenan, R.; Dunn, J.et al., *PRL*, **2005**, *94*, 103901

GRIP: 10 Hz, 150 mJ pumped

$$n_e = n_c * \alpha^2$$

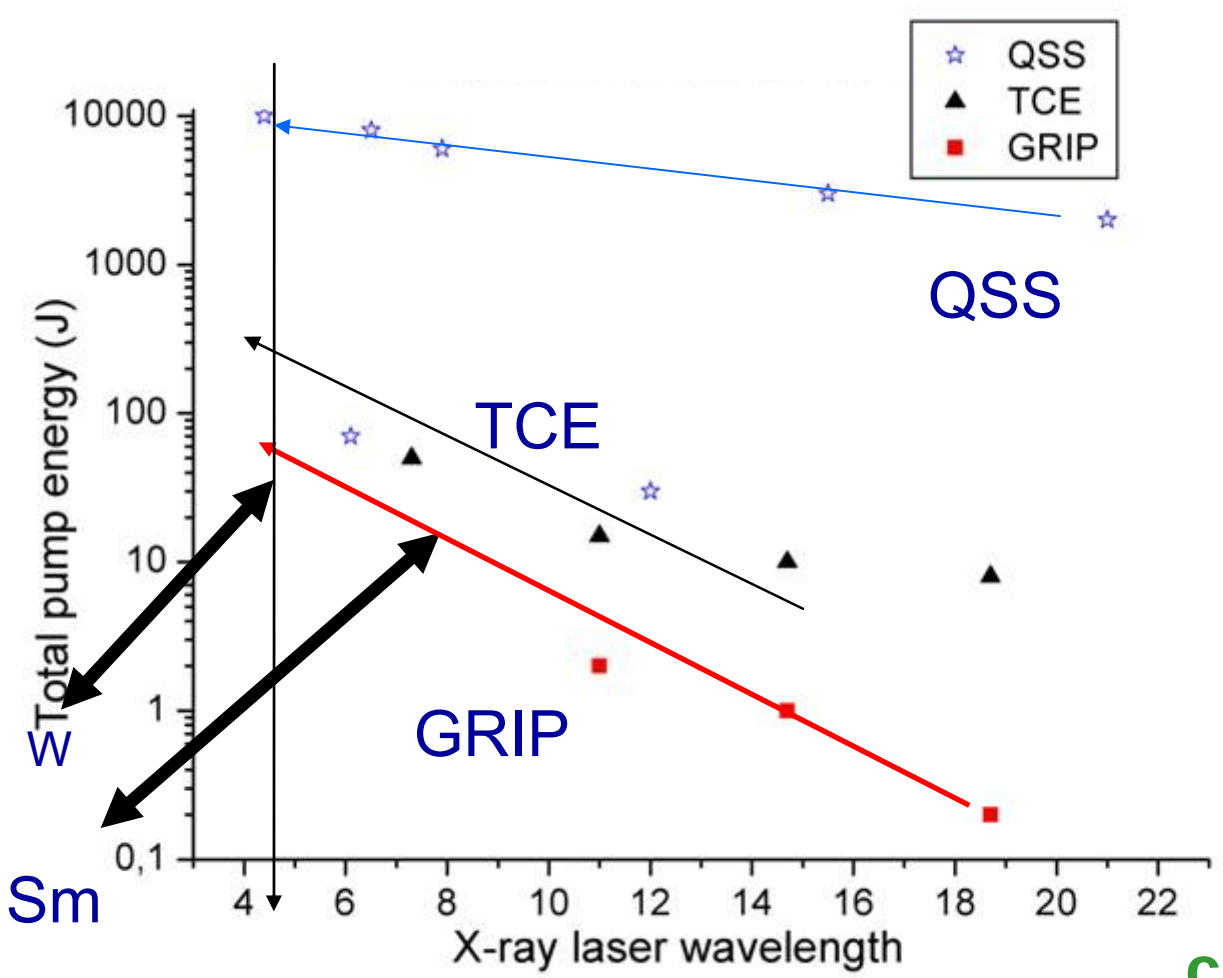




Neumayer, P. et al.
Applied Physics B, **2004**, *78*, 957-959

short pulse with large incident angle: controls the electron density region where the energy is deposited

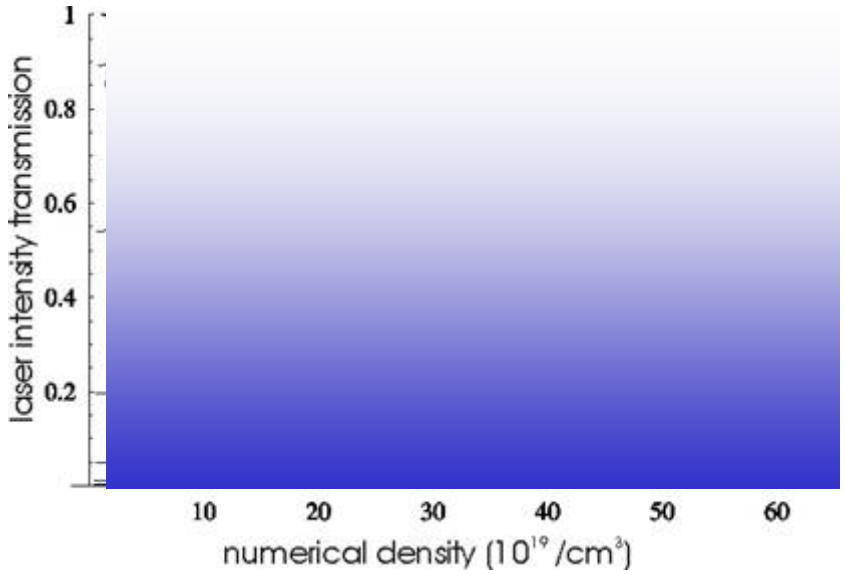
Energy for pumping XRL

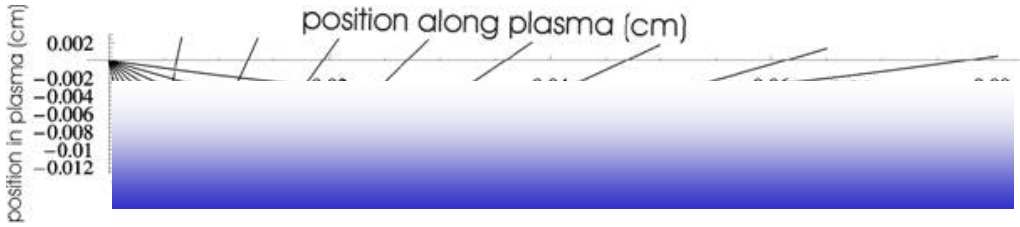


OFI and HHG

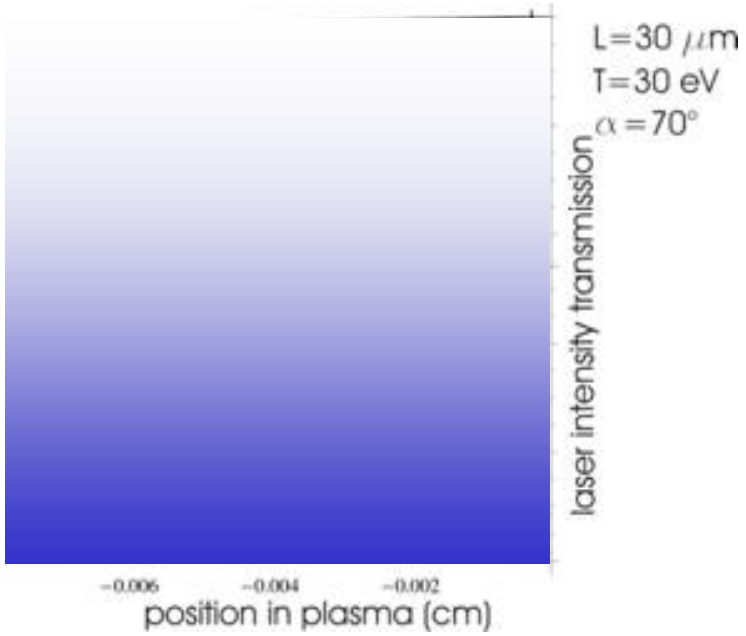
capillary targets for OFI: high quality beam profile

Modeling main pulse absorption in plasma at different incidence angles





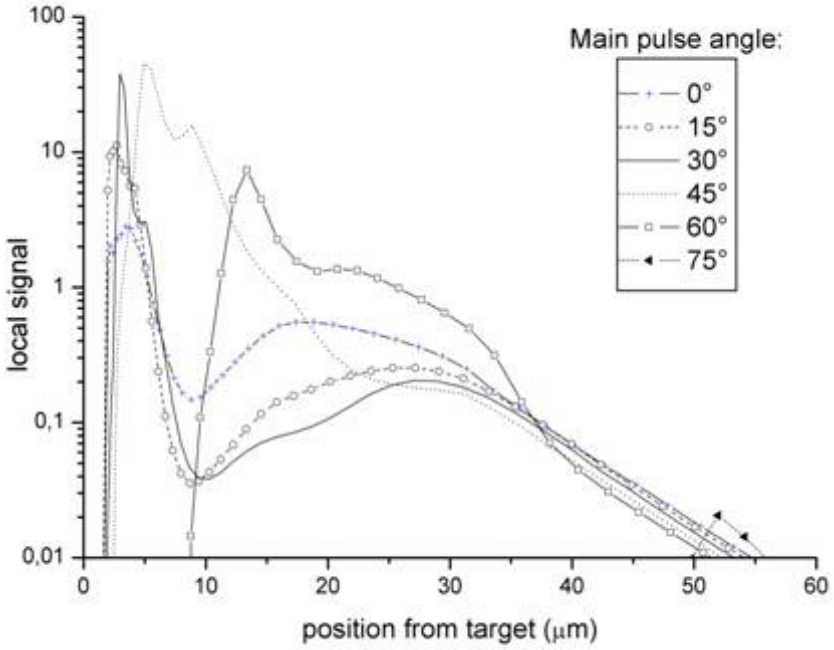
Inverse Bremsstrahlung absorption: non-linear factor Zf(I_{laser}, T_{plasma}):



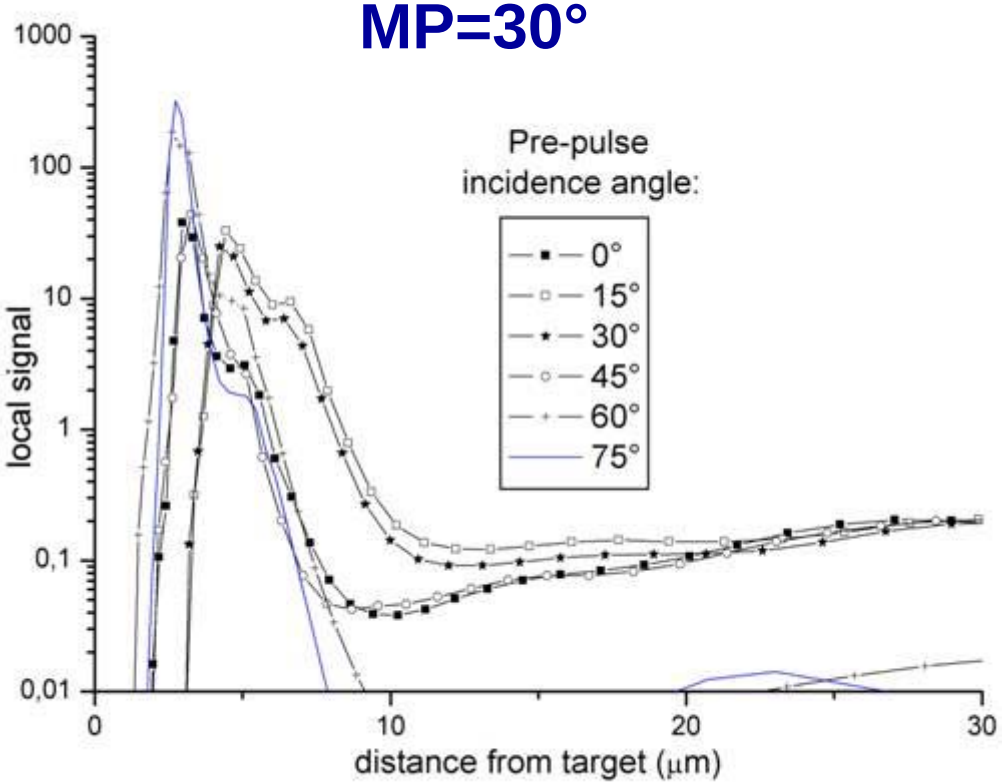
short pulse angle: controls the electron density region
short pulse intensity: controls the energy deposition

PP and MP incidence angle effects

PP=0°



MP=30°

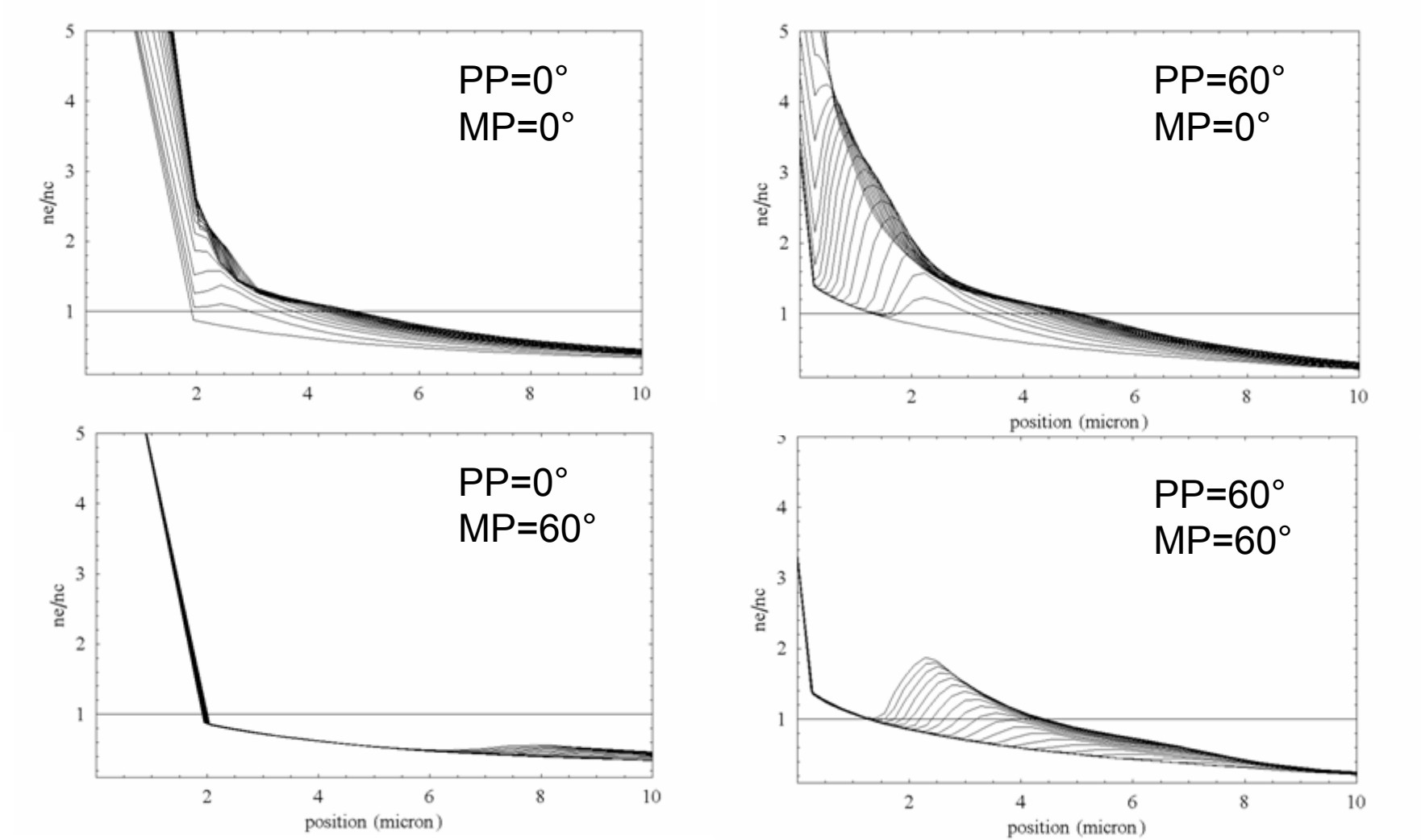


$$s_l = \frac{n_e}{n_c} \cdot (e^{gl} - 1)$$

D. Ursescu, D. Zimmer, T. Kühl, B. Zielbauer, G. Pert;
Gain generation in the critical density region of a TCE XRL;
Proceedings for the ICXRL10, Berlin 2006

Pre-pulse angle: controls the pre-plasma gradient

Electron density distribution dynamics



Electron density normalized to critical electron density
for different pre-pulse and main pulse angles over 20 ps time evolution

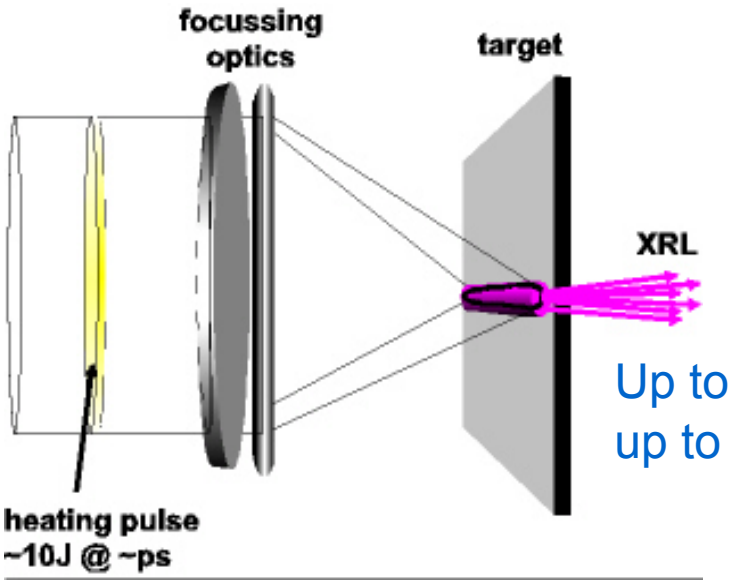
Pre-pulse angle: allows the shaping of the plasma

X ray lasers for spectroscopy experiments

LIXAM, Université Paris-Sud 11
Gesellschaft für Schwerionenforschung
Johannes Gutenberg-Universität Mainz
INFLPR, Bucharest
Lawrence Livermore National Laborat
University of York

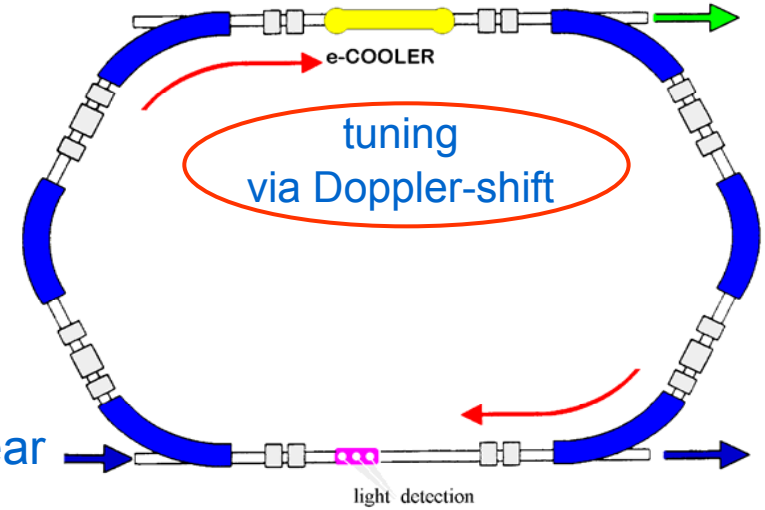
Li-like ions spectroscopy

principle of an x-ray laser



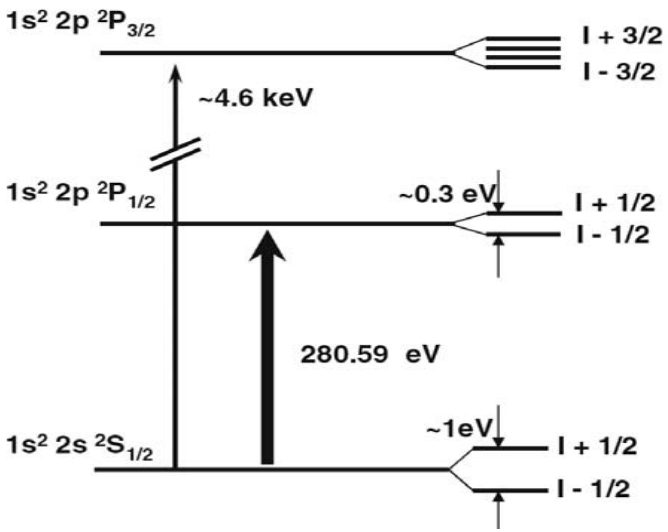
Up to few mJ
up to 300 eV

excitation in the ESR/NESR



anti-collinear

up to Z=92 possible



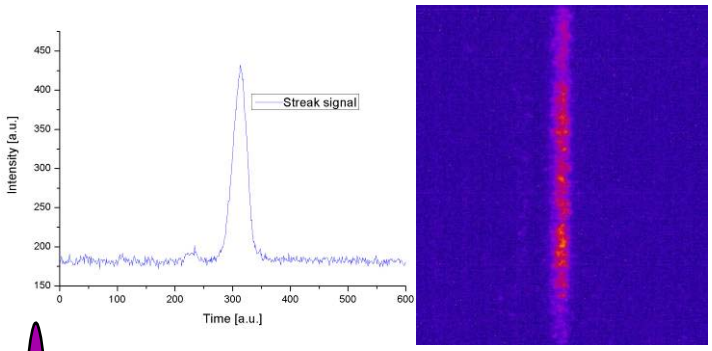
$\Delta p/p \sim 5 \times 10^{-5}$ @ NESR: wide range of accessible ions

XRL experimental set-up: Pulse configuration

Photo diode measurement

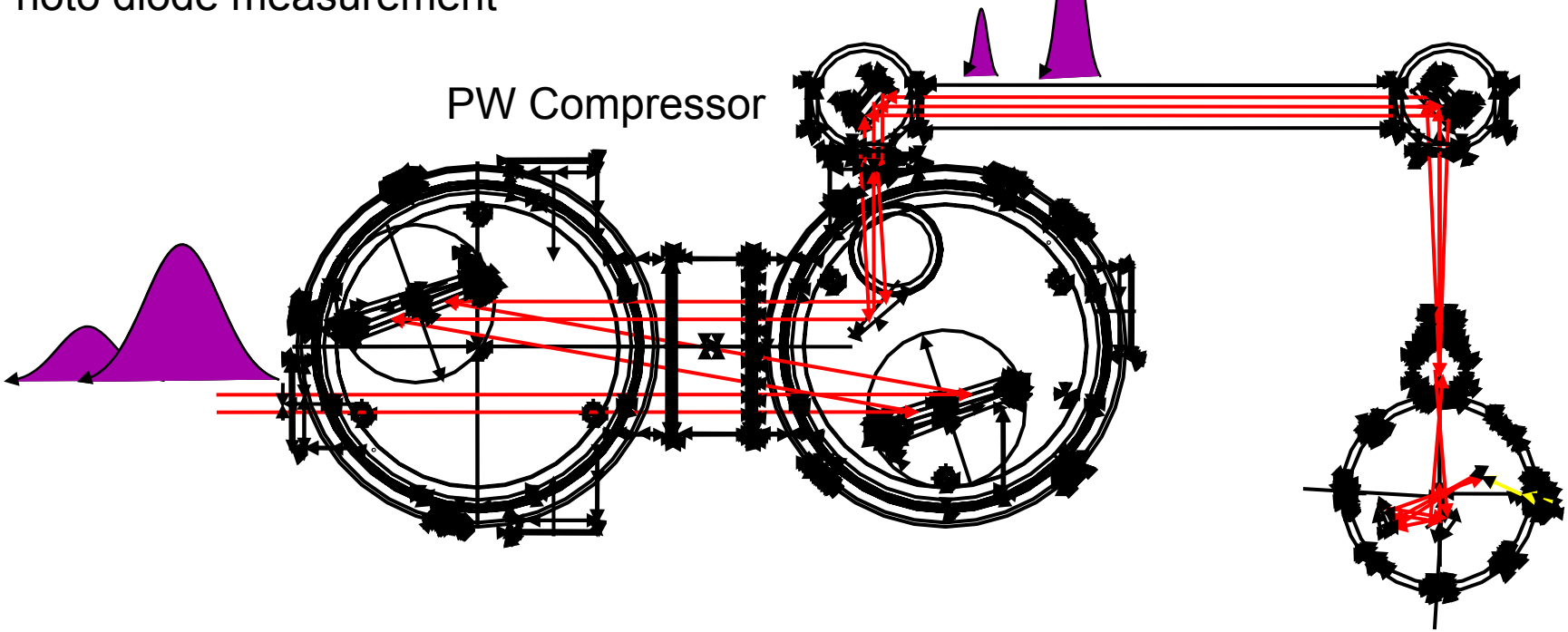
PP:5% MP:95%
Delay:1.8ns

Pulse duration: 100ps



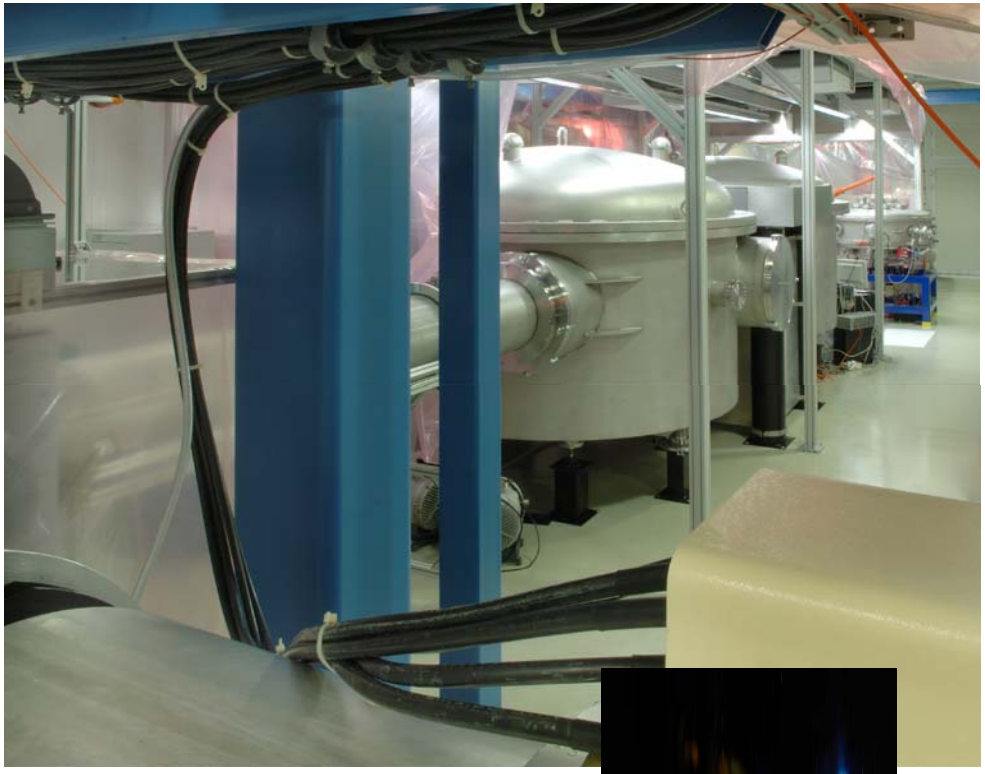
Streak camera measurement

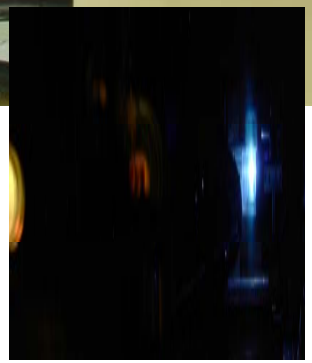
PW Compressor



180 eV X-Ray Laser pumped by compressed pulses from PHELIX

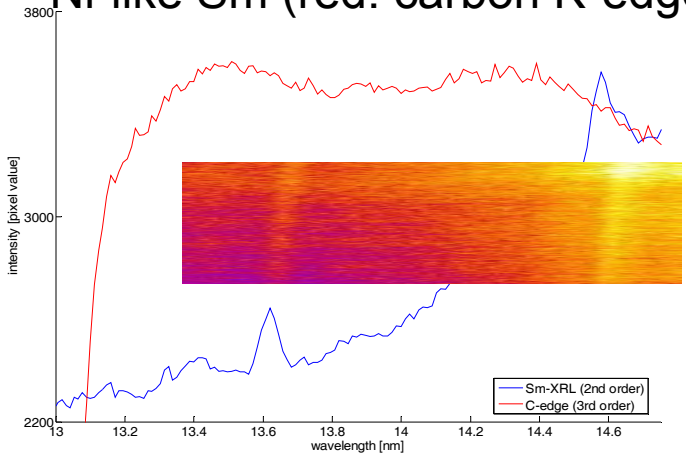
Compressor chamber in the PHELIX laser bay operating at 100 J / 50 ps for this experiment



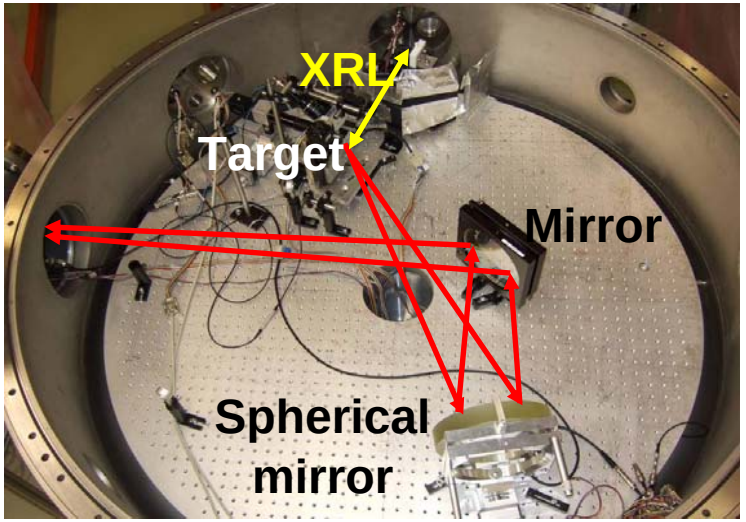


Plasma glow from samarium (Z= 62) x-ray laser target

Lasing lines at 6.8 and 7.3 nm in Ni-like Sm (red: carbon K-edge)



X-ray laser set-up



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