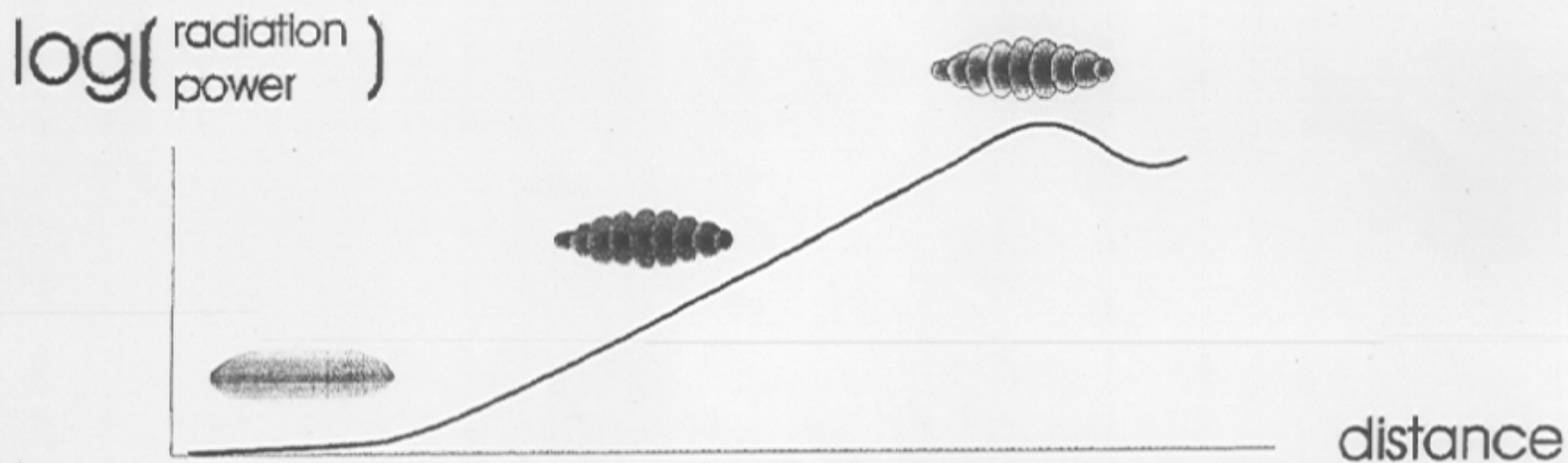
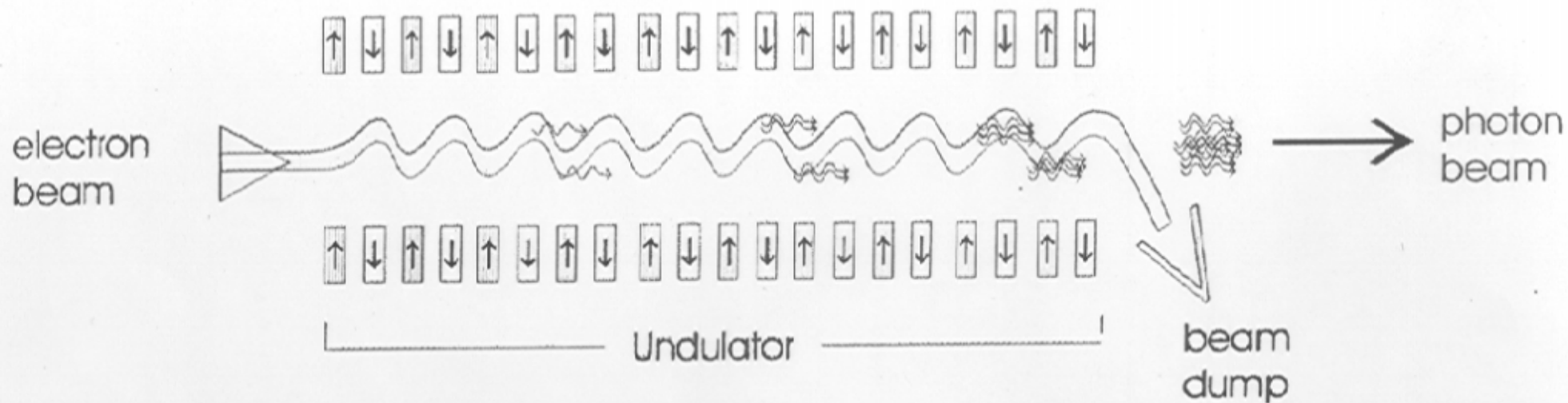


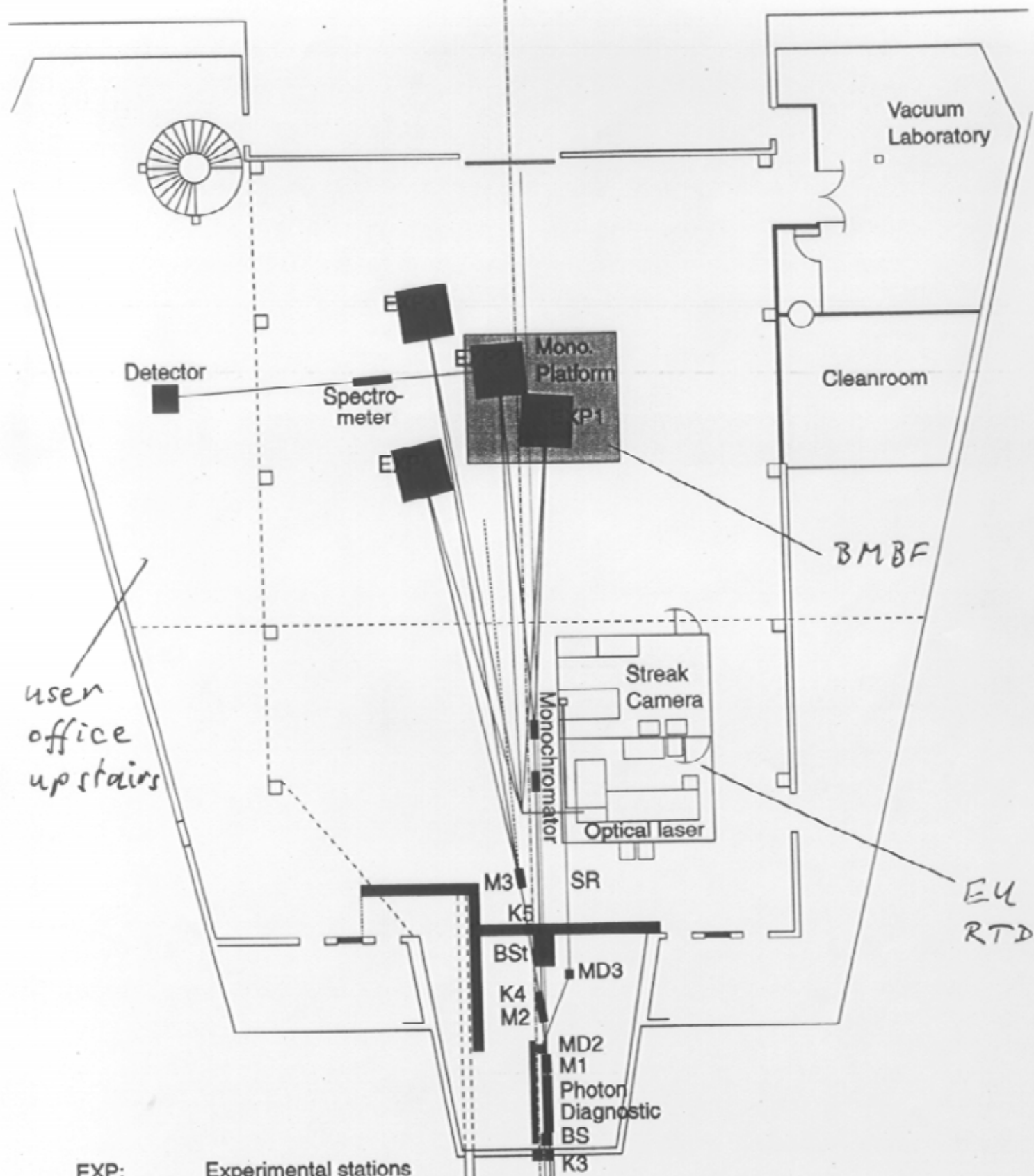
The VUV-FEL at DESY: Status, Results and Perspectives

Trieste December 5, 2001

- Overview and Concept**
- Performance**
- First Scientific Applications**
- Road map for a user facility**



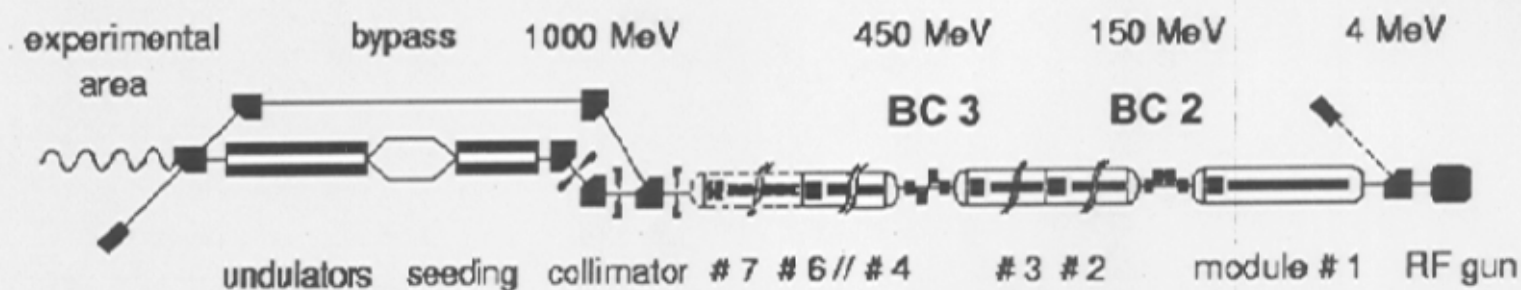
Free Electron Laser in the Self Amplified Spontaneous Emission (SASE) mode



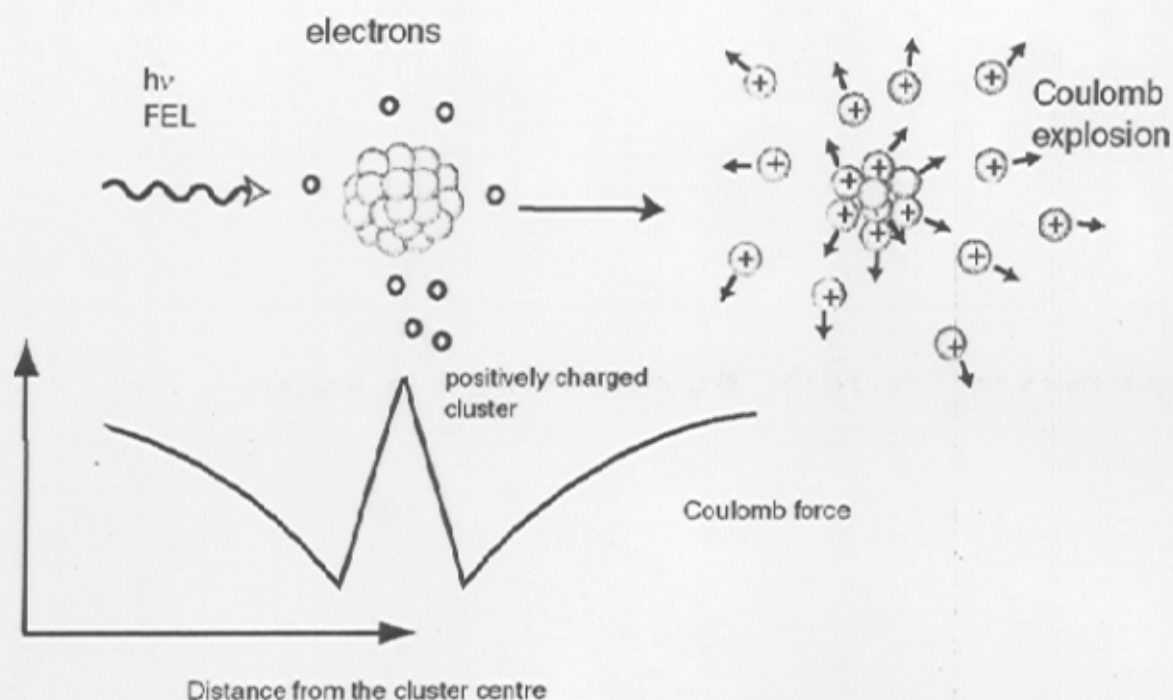
- EXP: Experimental stations
 M1-M3: Mirrors for FEL radiation
 MD1-MD3: Mirrors for vis./UV SR
 SR: vis./UV synchrotron radiation
 K3-K5: Collimators
 BS: Beamshutters
 BSt: Beamstop

Layout of the FEL Phase II

TTF Phase II

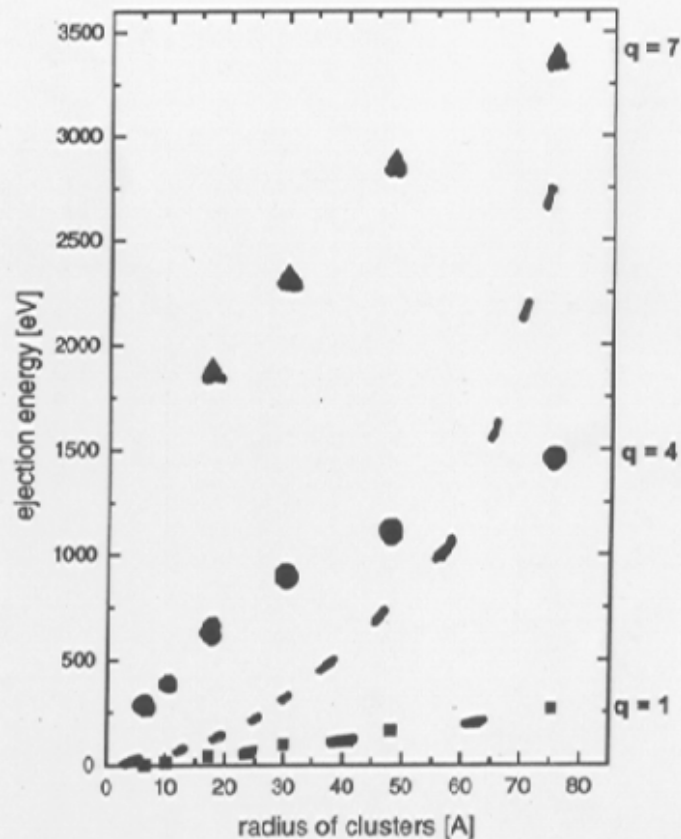


Do we understand the results?

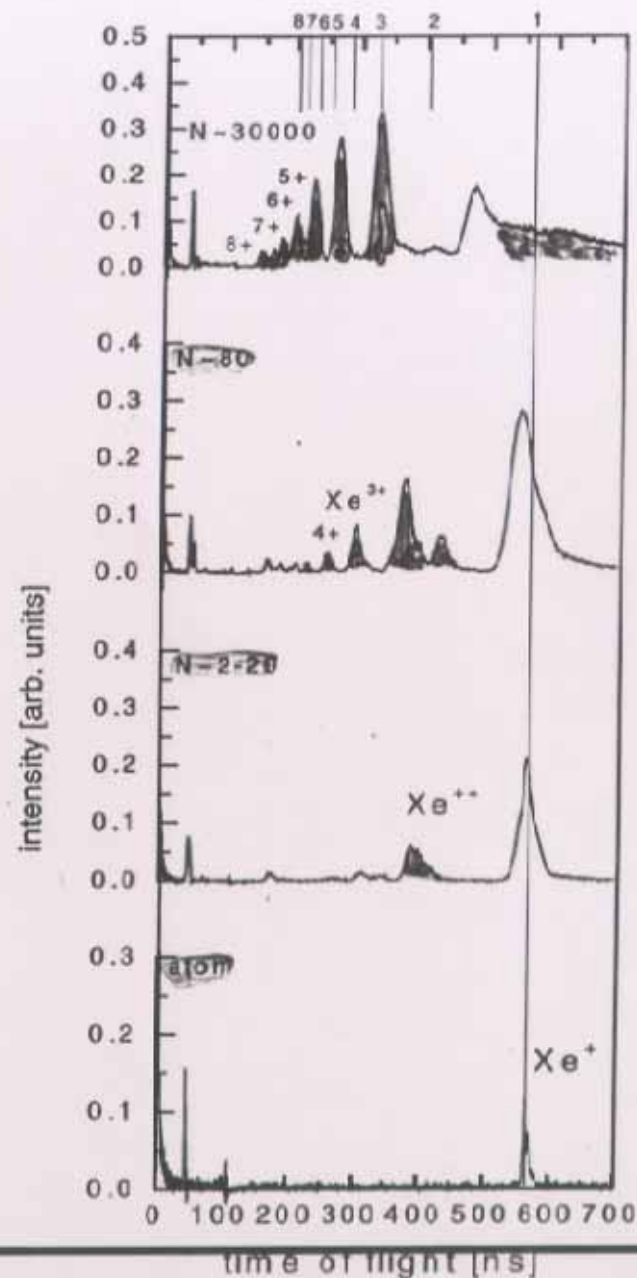


**Nanoplasma formation: multi photon
absorption hot ions, cold electrons**

Ion energy as a function of cluster size



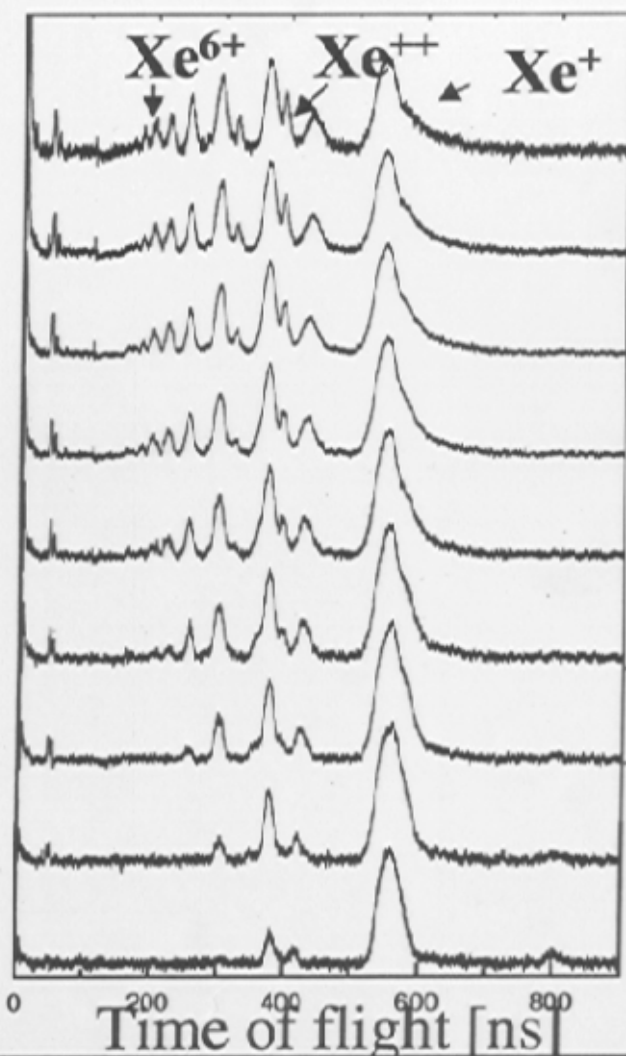
- Quadratic R dependence expected
- Absorption saturates
- Each atom in the cluster absorbs 10 photons



Dependence on the cluster size

- Single photon absorption in Xe atoms
- emission of highly charge ions from clusters (up to eight times charges)
- ions have high kinetic energy

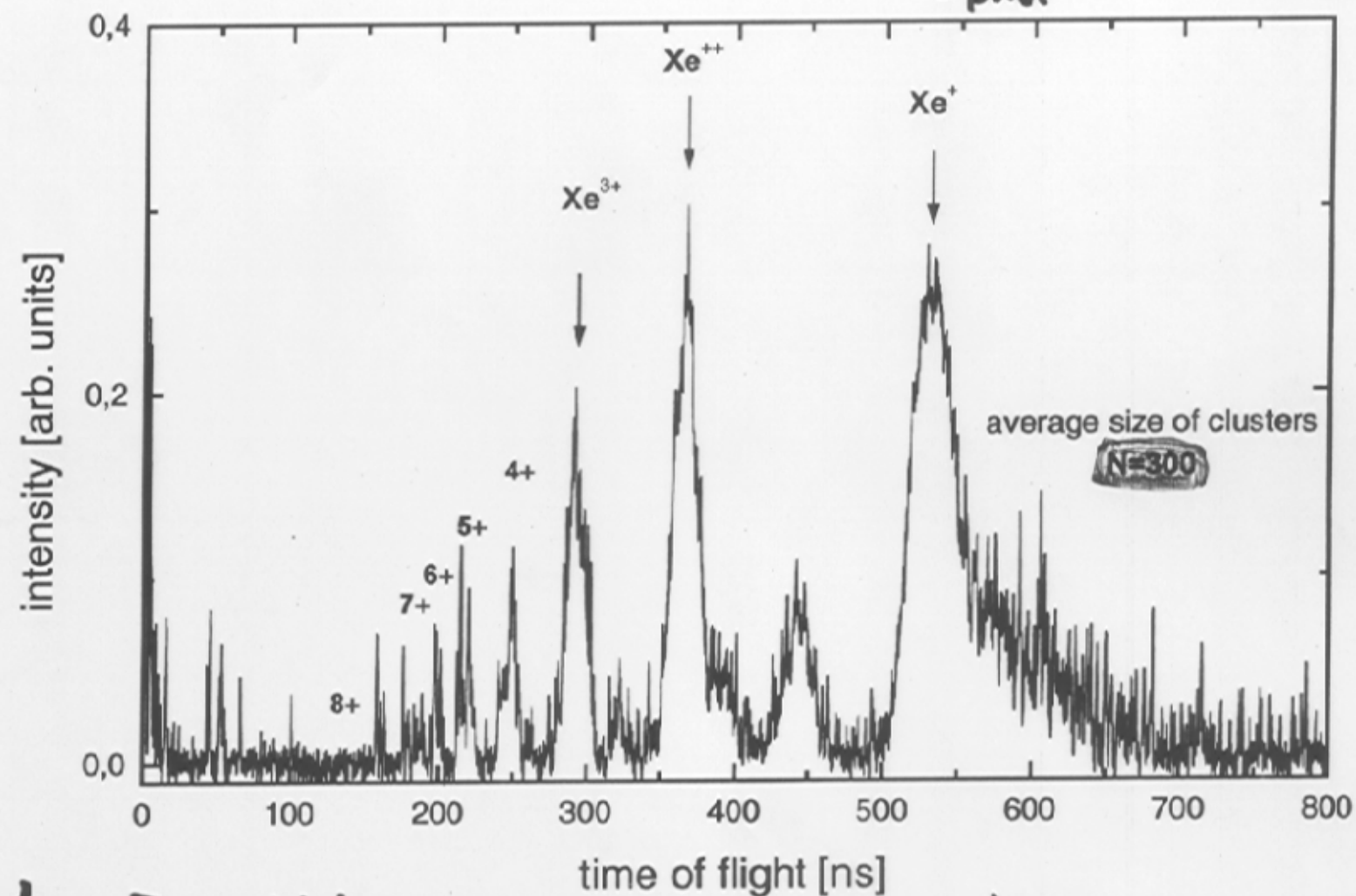
Dependence on the power density



Xenon clusters, 50 atoms

$2 \times 10^{13} \text{ Watt/cm}^2$

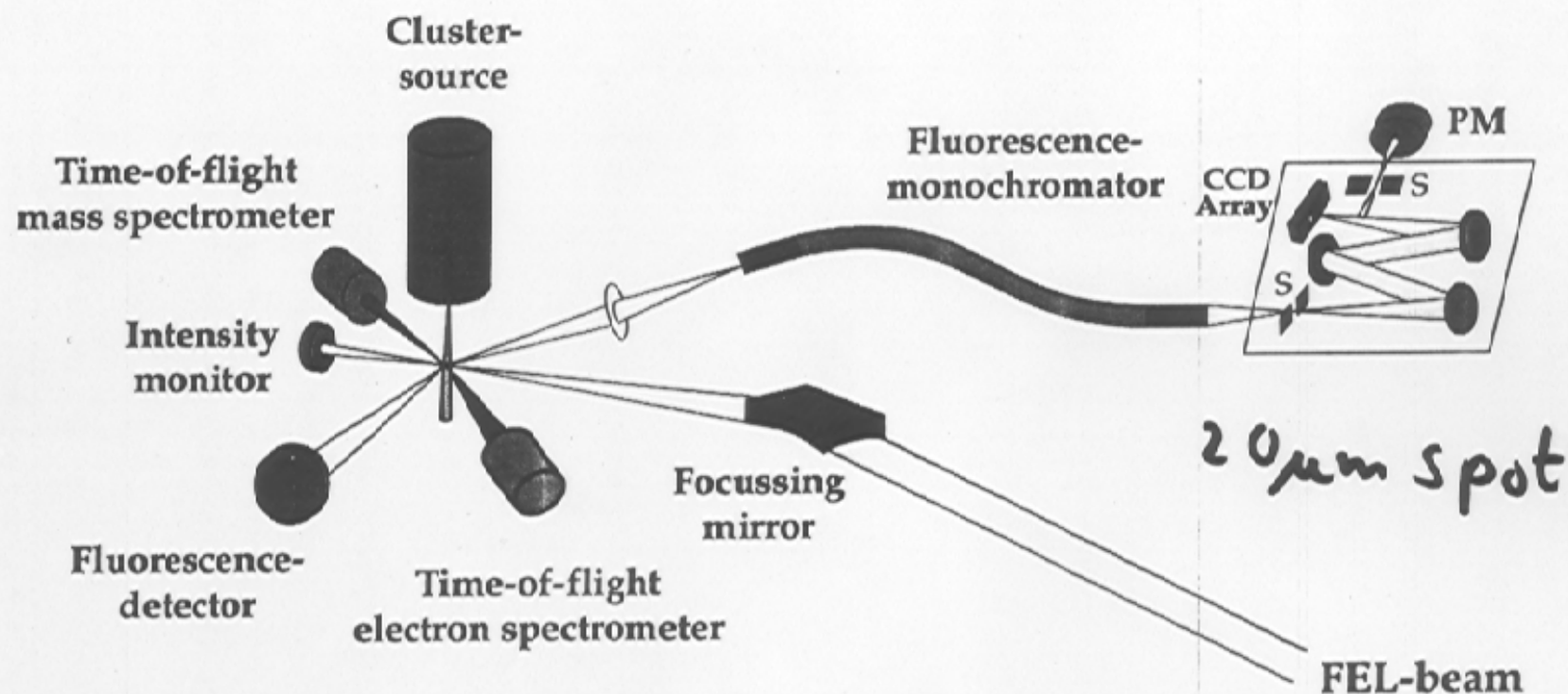
$1 \times 10^{12} \text{ Watt/cm}^2$



$\sigma = 50 \text{ Mbarn}$

(single photon ionisation)

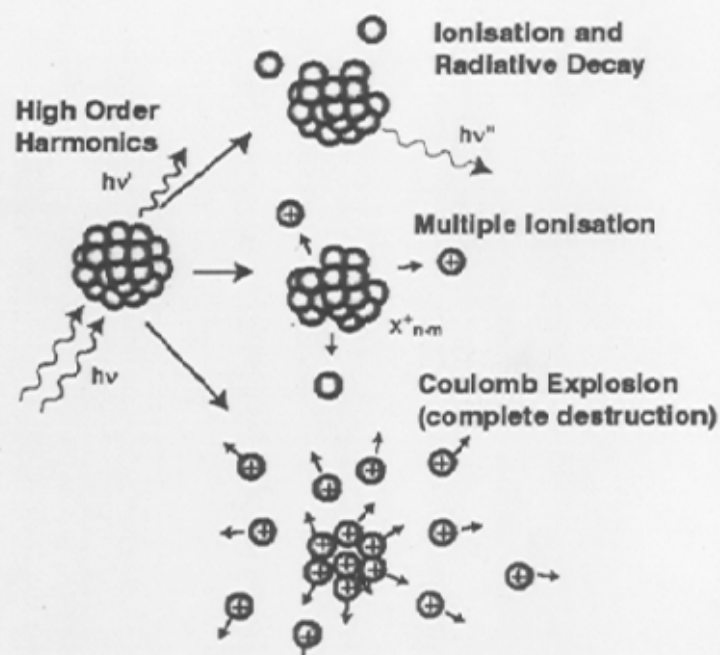
FEL Cluster-Experiment



H. Wabnitz, J. Schulz, P. Gürtler, W. Lenzsch, A. Swidzinski

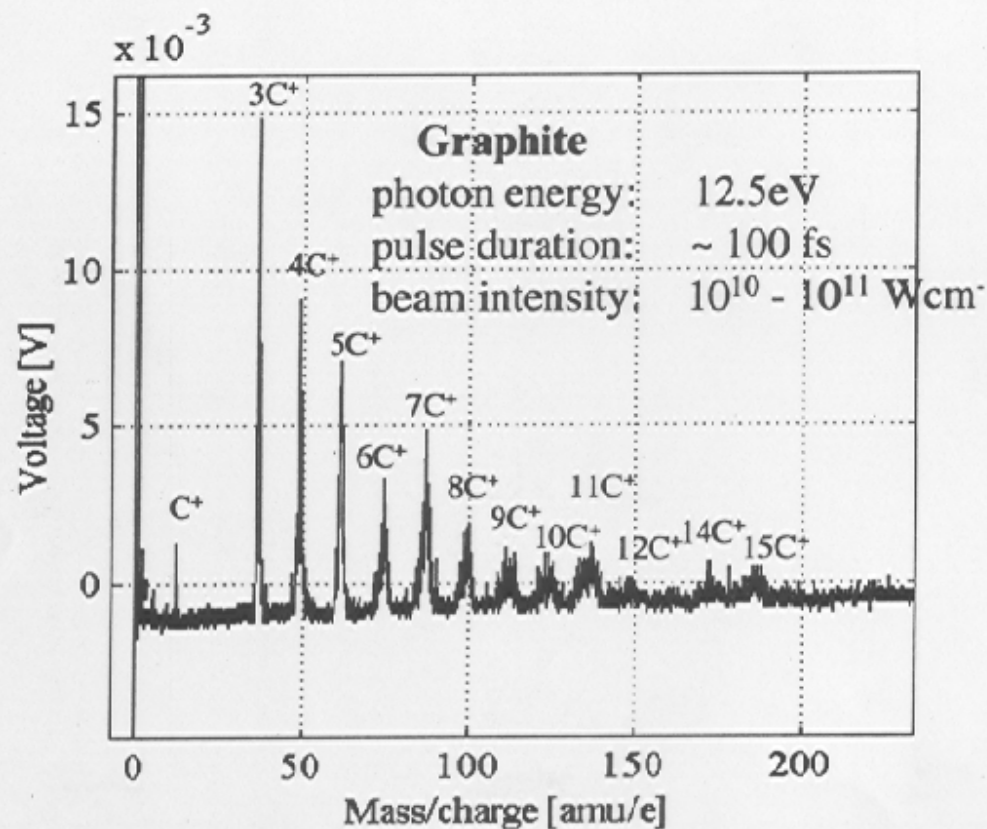
T. Lenzmann

Idea of the cluster experiment: Interaction of intense soft x-rays with matter



- which multi-photon processes are observed
- cross sections (surface, bulk)
- which ions are prepared (charge state, electronically excited states)
- life time of intermediate states
- high-order harmonic generation

Experimental results



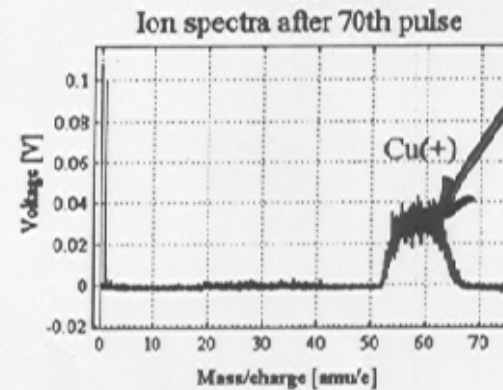
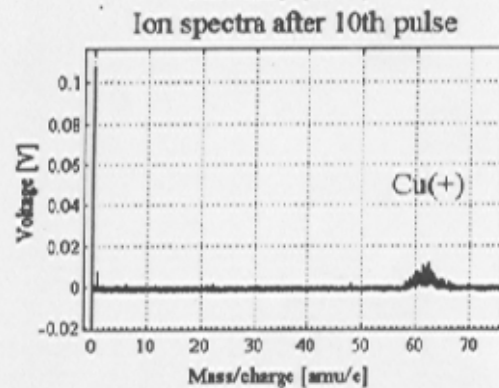
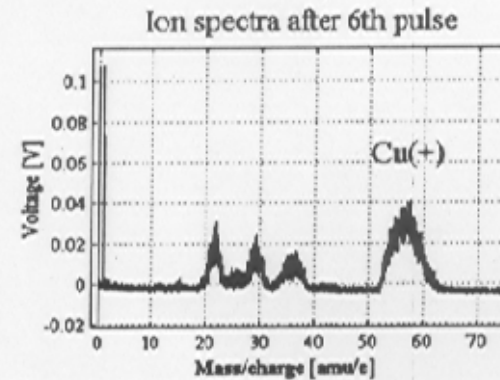
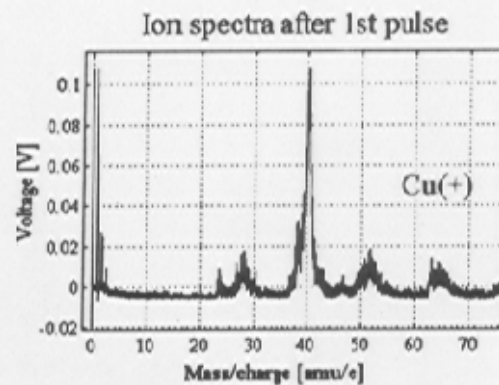
Estimated damage thresholds:

Sample/thickness damage threshold [J/cm^2]

Cu	bulk	0.5
Au	10 nm	0.04
Si	bulk	0.03
Graphite	40 nm	0.06
YAG	bulk	0.07

Ablation from a Cu surface

Ion spectra from Cu sample for different number of pulses.



100 eV
kinetic
energy

Investigation of the damage threshold of optical components at the VUV TESLA FEL Phase I

J.Krzywiński^{1,2},
A.Andrejczuk^{1,3}, U.Hahn²,
M.Jurek^{1,2}, J.Pełka^{1,2},
W.Sobala⁴, M.Sikora⁵,
R.Sobierajski^{2,6}

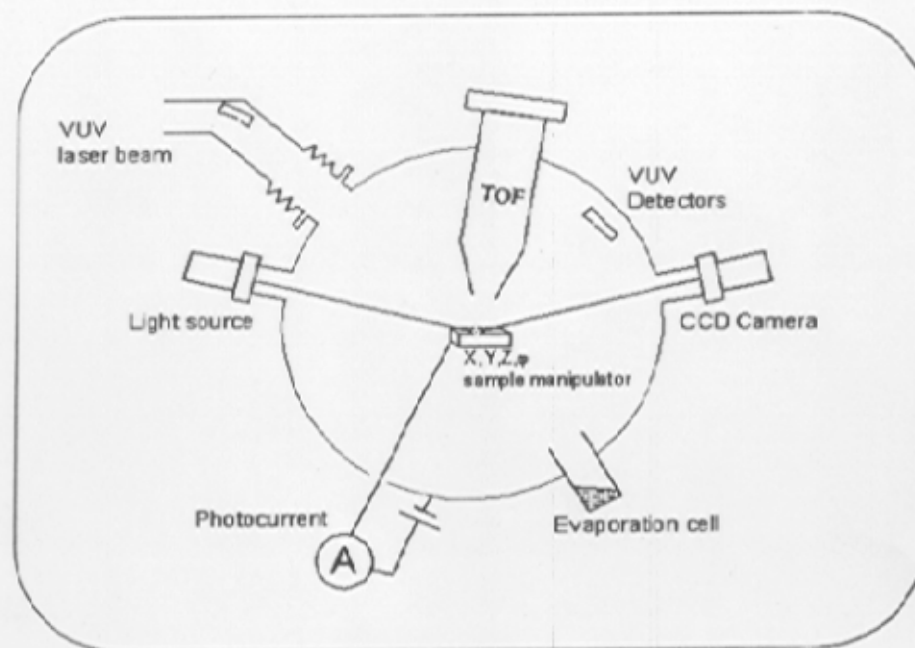
¹Polish Academy of Sciences,

²HASYLAB at DESY, Germany,

³University of Białystok,
Poland, ⁴Institute of Nuclear
Physics, Cracow, Poland

⁵University of Mining and
Metallurgy, Cracow, Poland

⁶Warsaw University of
Technology, Poland



Pulse length

100 fs

Pulse energy

10-100 uJ

Wavelength

98 nm

Spot size

100 μ m

Max. power density

$\sim 10^{13}$ W/cm²

Scientific applications: Classes of Experiments

„high-flux“ experiments

- experiments on dilute samples
- optical non-linear processes

**Clusters
Ablation of surfaces**

experiments using the coherence

- speckle, e.g. in combination with magnetic contrast

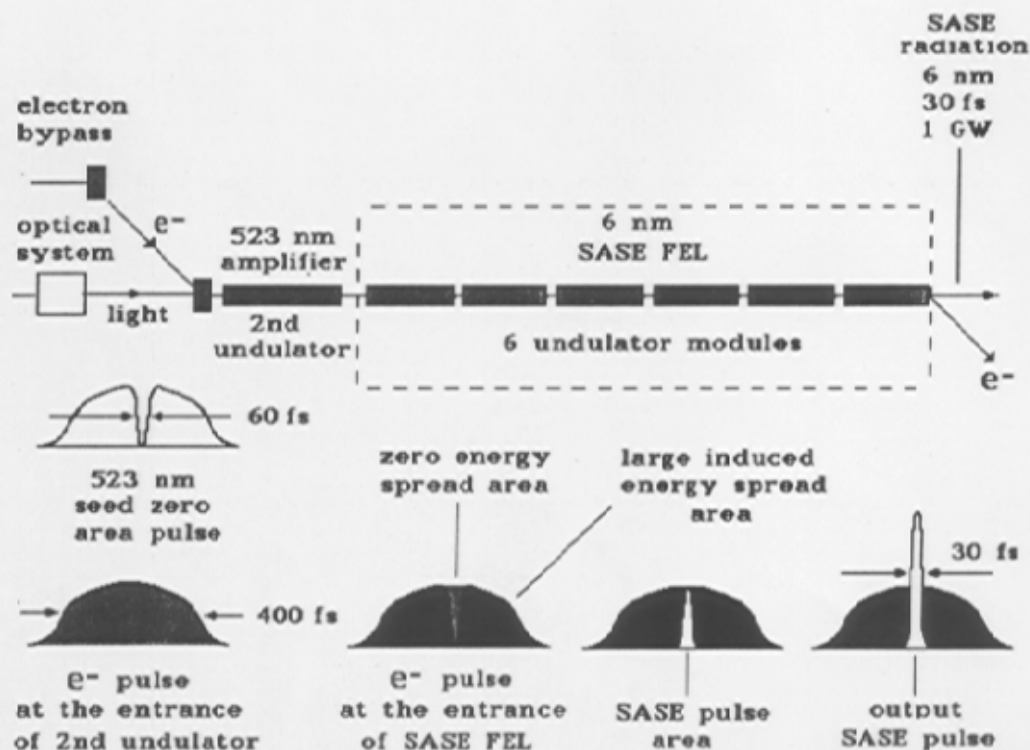
time resolved experiments

- pump-probe experiments to study dynamics on a
- femto second time scale (nuclear motion, electron
- relaxation)
- fast magnetic switching

New Methods for the Generation of Femtosecond Soft X-ray Pulses

E. Saldin, E. Schneidmiller, M. Yurkov et al

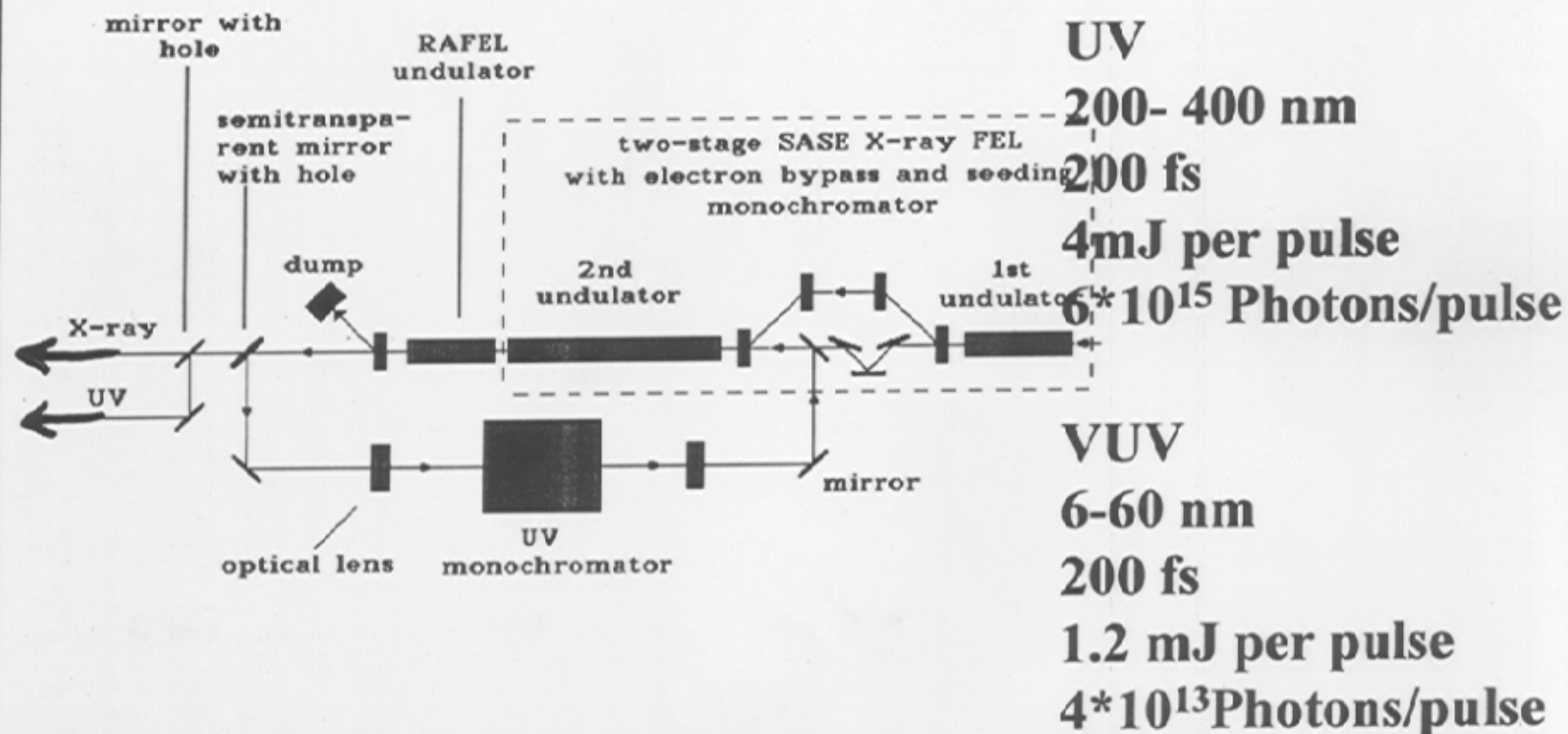
Amplification of temporally shaped pulses



30 fs VUV pulses

New Pump-Probe Facility combining a High Power UV FEL Regenerative Amplifier with a Soft X-ray SASE FEL

E. Saldin, E. Schneidmiller, M. Yurkov et al



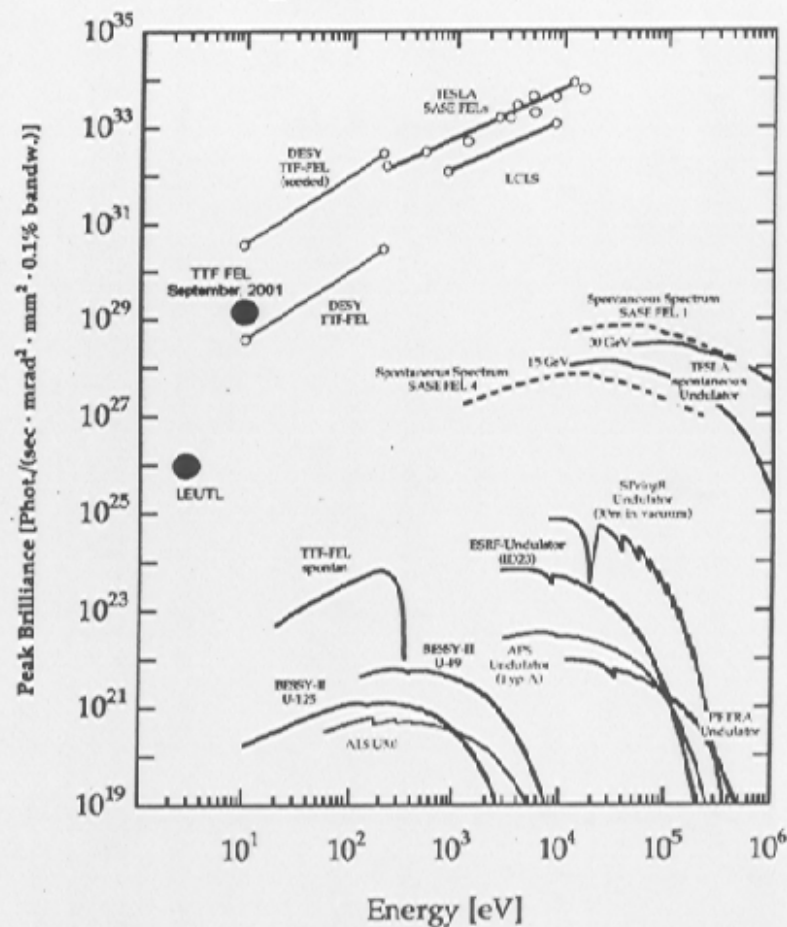
Parameters

• Radiation wavelength	95-105 nm	
• Radiation pulse energy at saturation	30-100 ~~nJ~~	
• Radiation pulse duration (FWHM)	30-100 fs	←
• Radiation peak power	1 GW	
• Radiation average power up to	5 mW	
• Spectrum width (FWHM)	1%	
• Radiation spot size [FWHM]	200 ~~nm~~	
• Radiation angular divergence [FWHM]	260 ~~μrad~~	

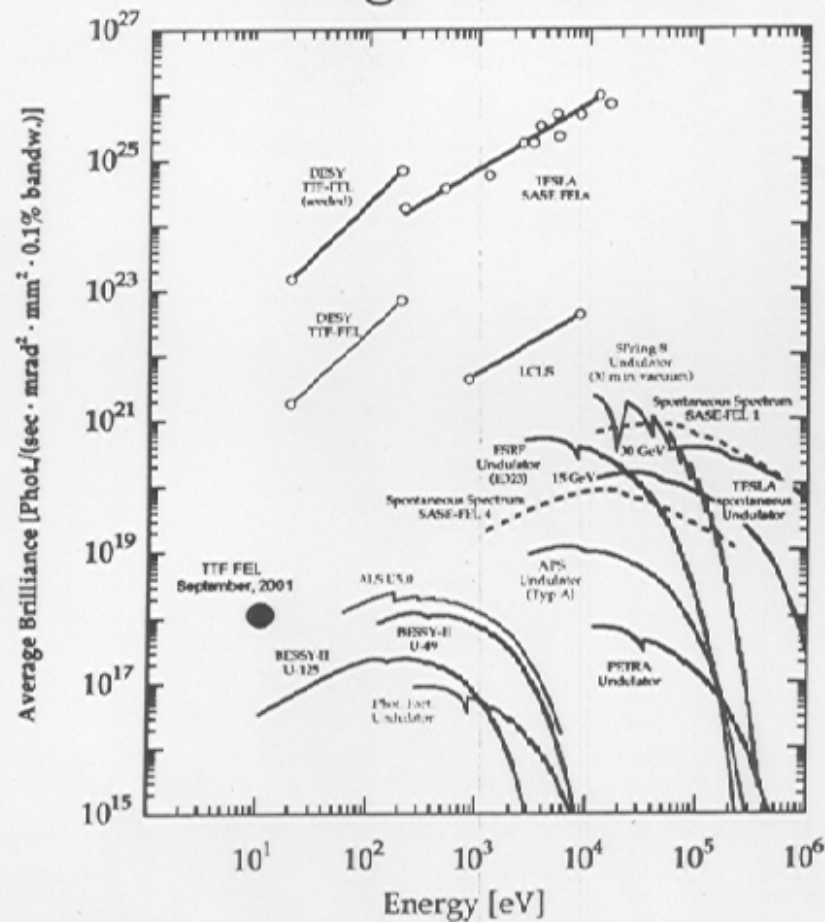
• Electron beam energy	240-250 MeV	
• Bunch charge	2.8 nC	←
• Peak beam current up to	1.3 kA	←
• Charge in radiative part of the beam	0.2 nC	
• Duration of radiative part of the beam	100-150 fs	
• rms normalized emittance	5-7p mm-mrad	

Performance

peak brilliance

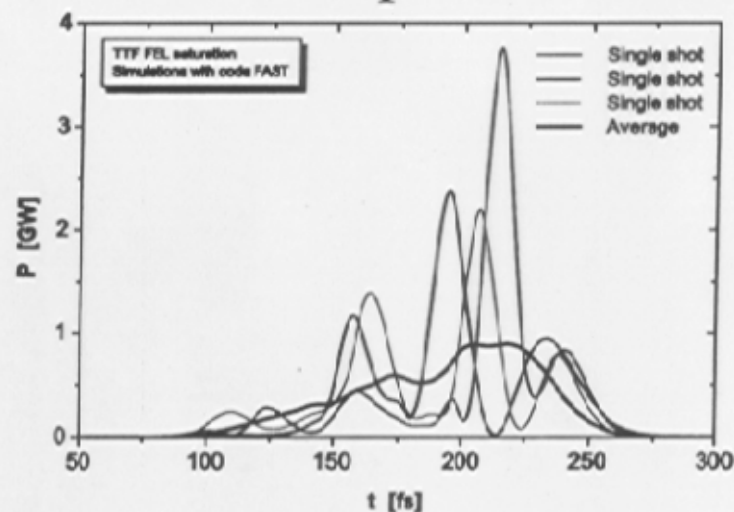


average brilliance

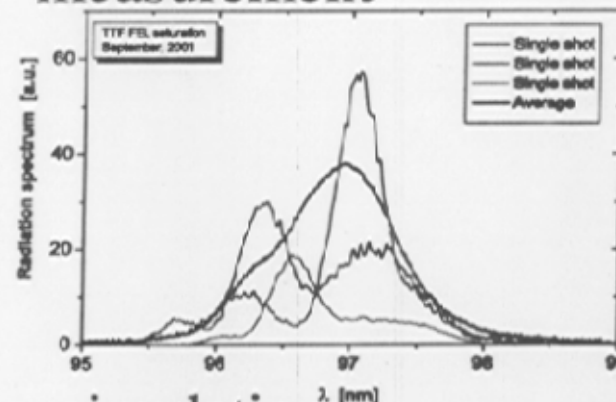


Time and spectral distribution

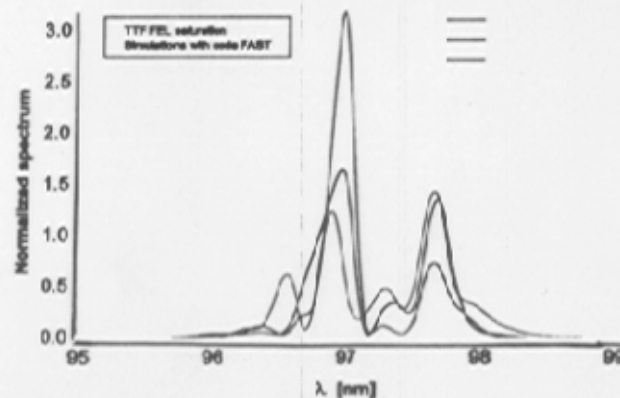
Simulated temporal distribution



measurement



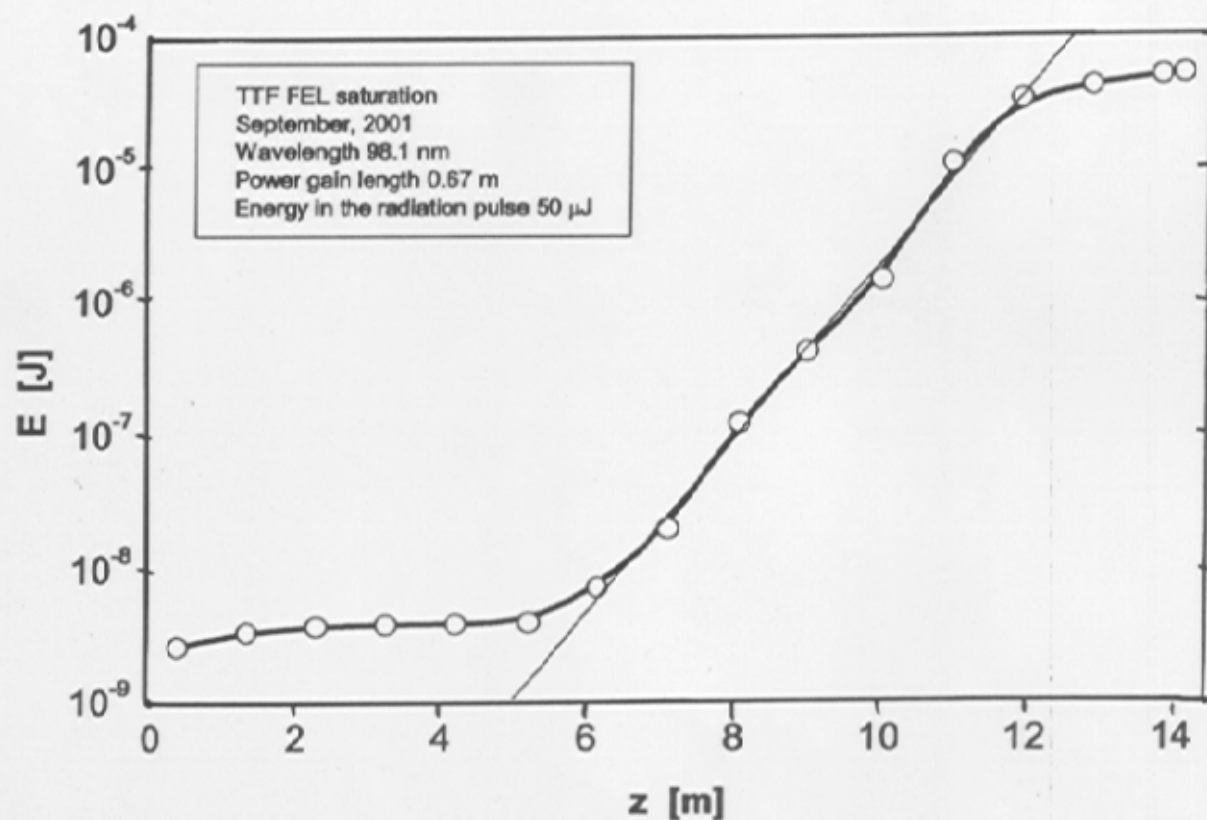
simulation



Pulse length 50-100 fs (FWHM)

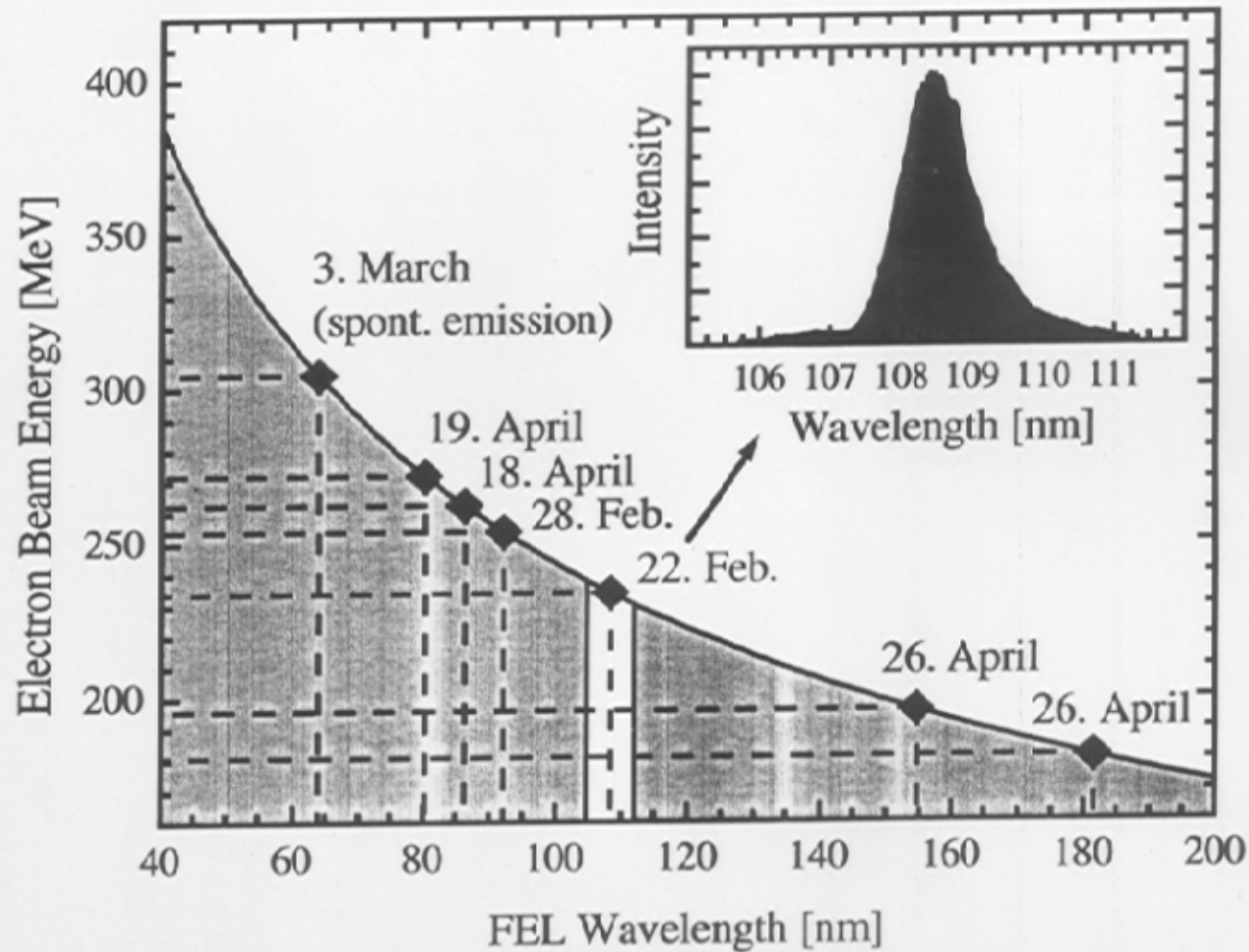
M. Yurkov et al

Intensity versus undulator length



M. Yurkov, J. Rossbach et al

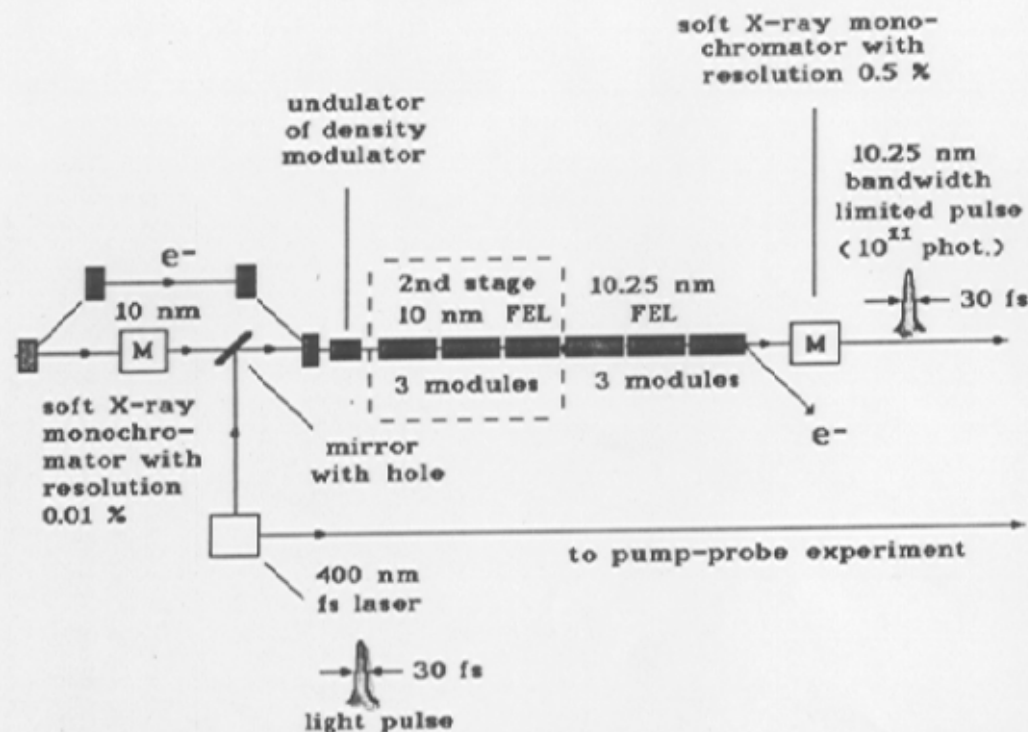
Lasing at TTF FEL



J. Feldhaus, C. Gerth, R. Treusch 2000

New Methods for the Generation of Femtosecond Soft X-ray Pulses

E. Saldin, E. Schneidmiller, M. Yurkov et al

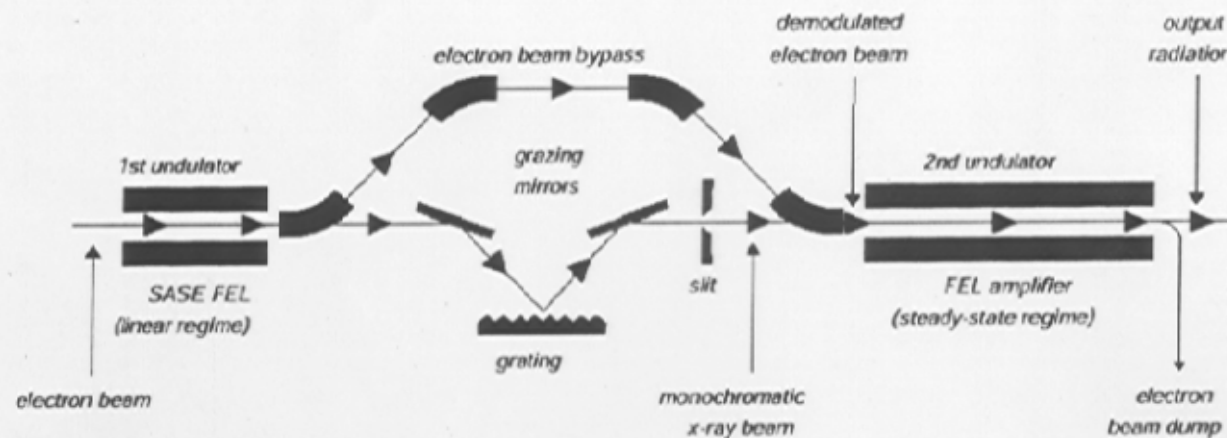


fs optical laser
pulses modulate the
electron beam $\Rightarrow$
side bands with
frequency

$$\omega_0 \pm \omega_{\text{laser}}$$

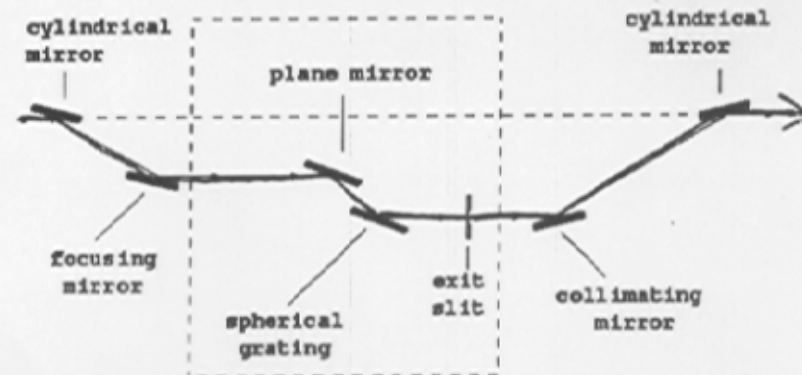
Band width limited pulses ~ 10 nm
30 fs, 10^{11} Photons/pulse

Seeding Option



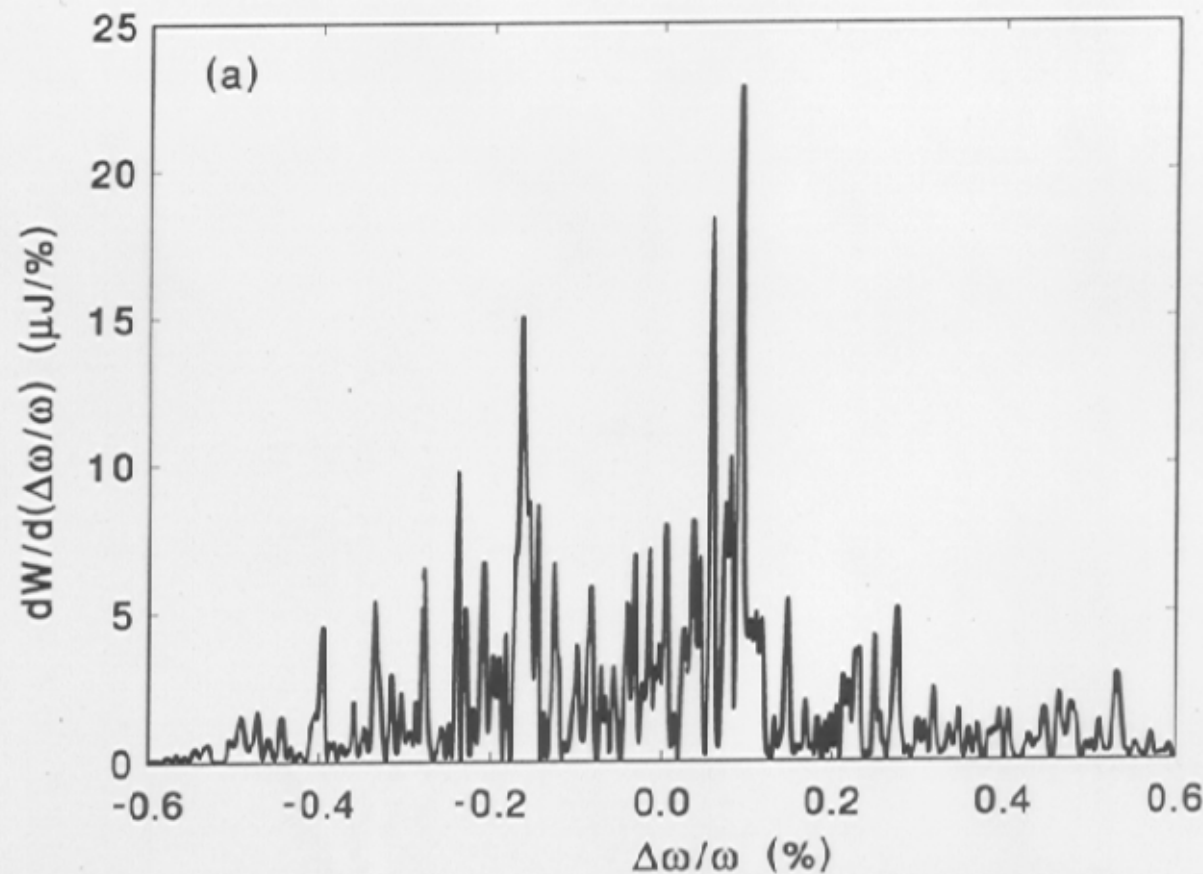
Fourier transform limited
pulses bandpass 10^{-5}

J. Feldhaus, E. Saldin,
M. Yurkov et al



funded by BMBF
(Helmholtz fund)

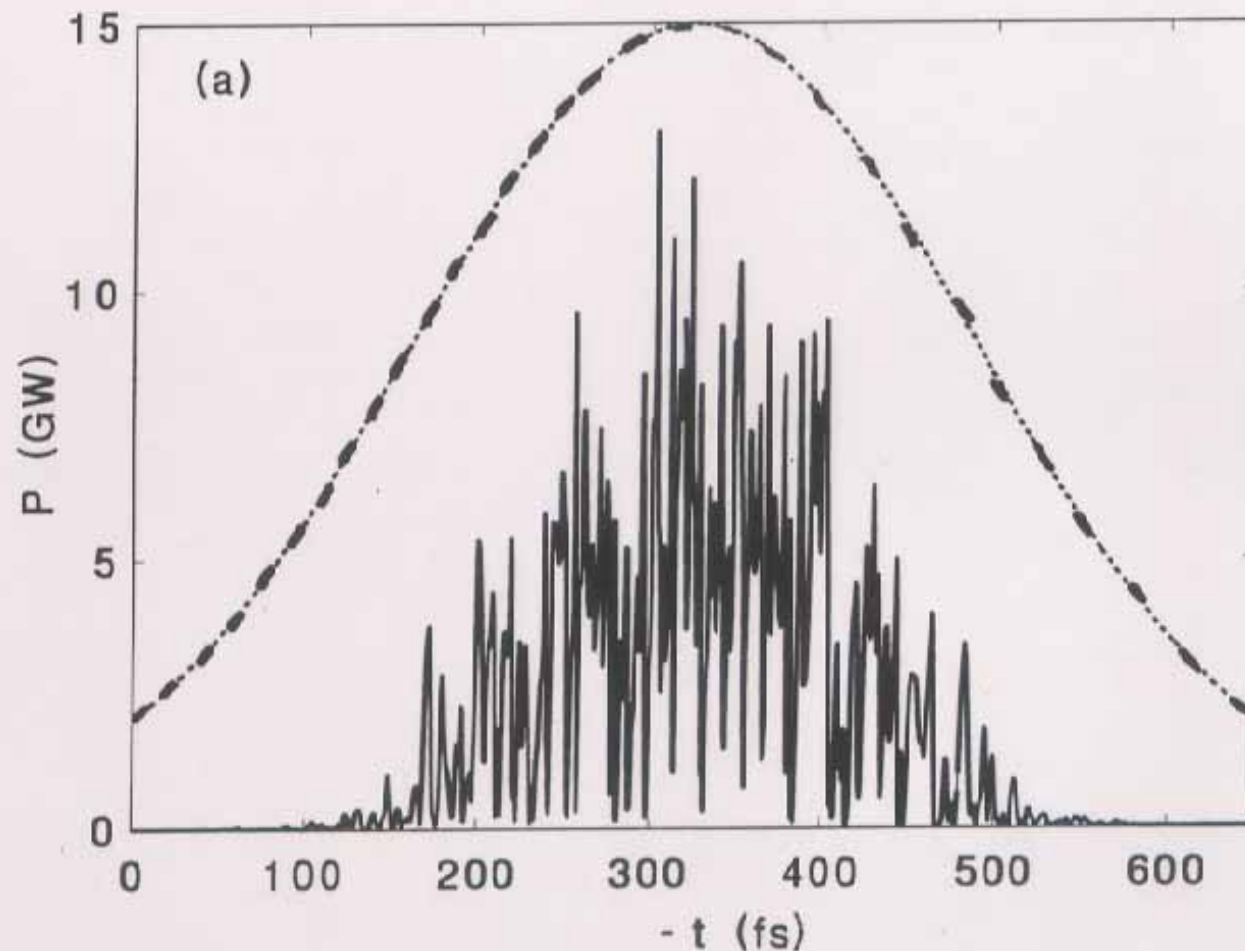
Spectral Line Shape



Bandpass 0.4 %

Spikes

Temporal Pulse Shape



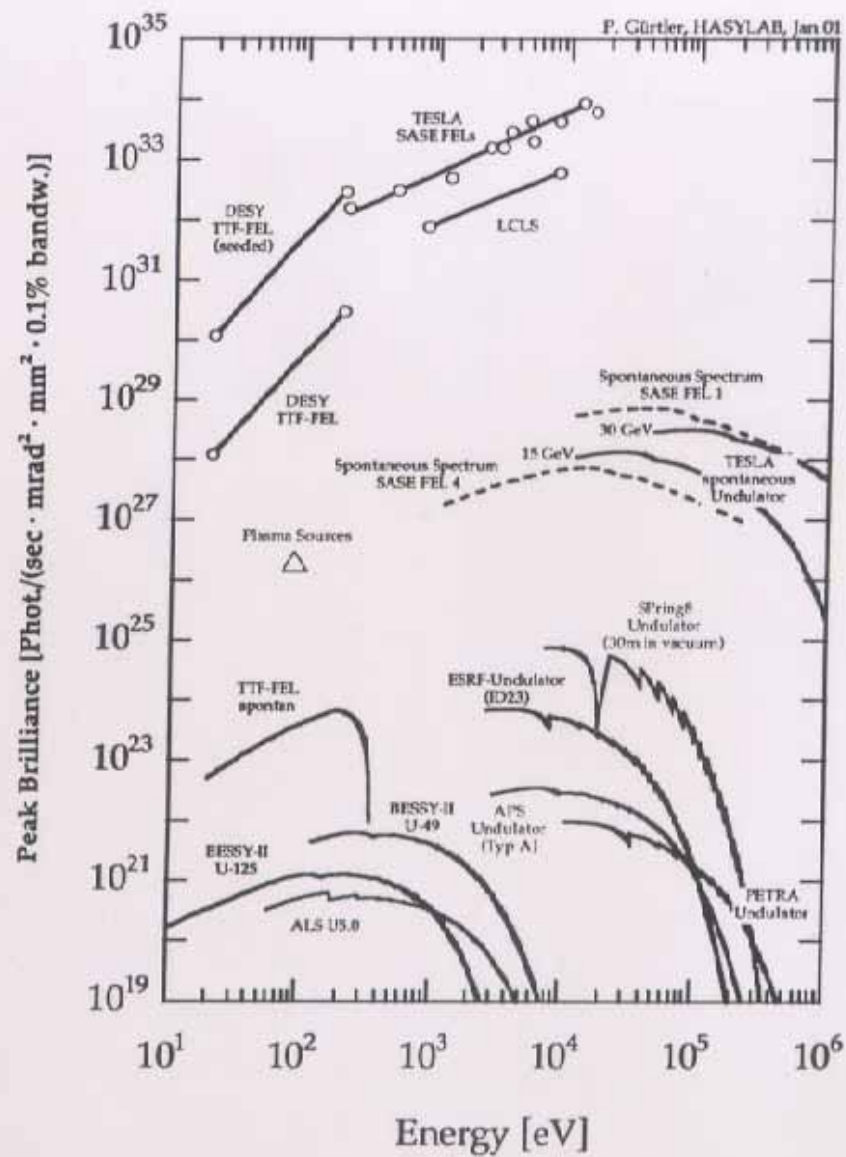
150 fs (photons)

Phase II

----- electrons

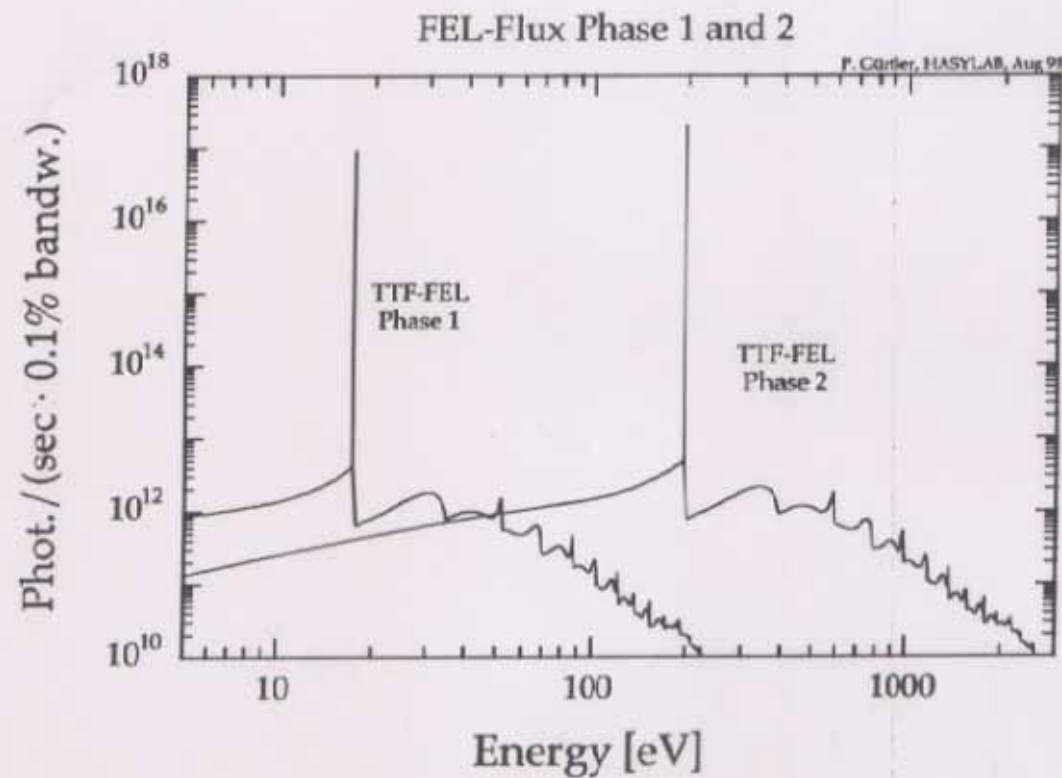
1000 fs

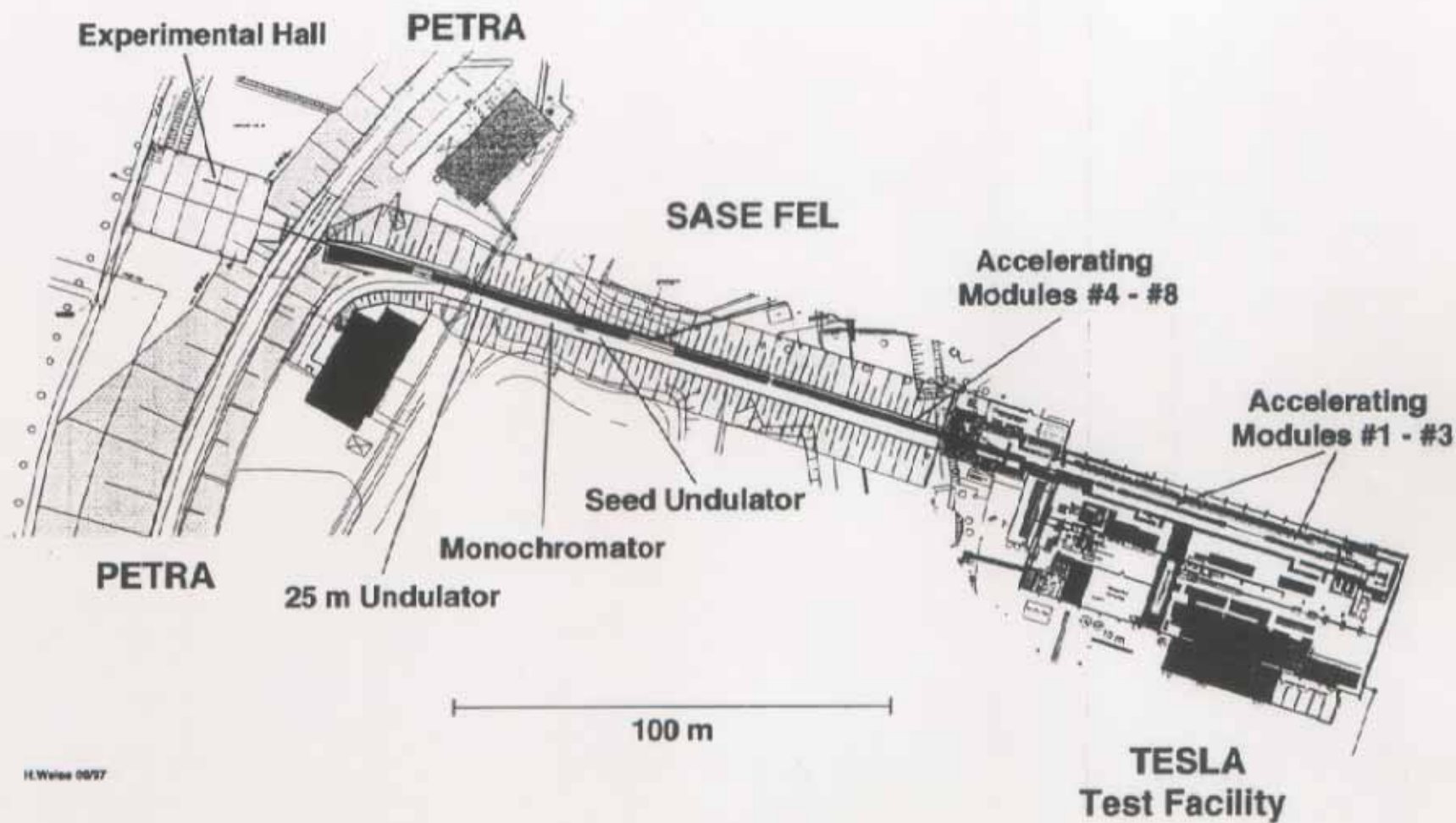
Phase I



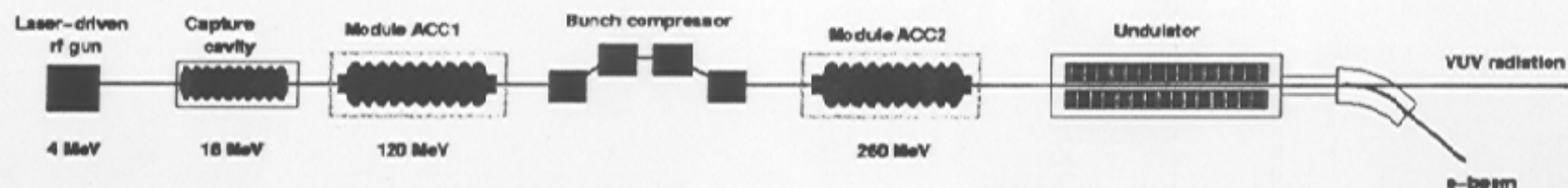
Peak Brilliance

Flux of Phase I and II FEL





Layout of the FEL Phase I



200 - 300 MeV superconducting
linac

180 - 90 nm

Requirements for a SASE-FEL

$$\lambda_{\text{phot}} = \lambda_u (1+k^2)/2\gamma^2$$

λ_u undulator period
 k undulator parameter
 γ relativistic factor

$$\epsilon < \lambda_{\text{phot}} / 4\pi$$

$\Rightarrow$ small emittance

$$L_s = \lambda_u / \rho$$

L_s Saturation length
 ρ FEL parameter
 $\rho = (k_2 r_e n \lambda_u J J^2(k) / 32 \pi \gamma^3)^{1/3}$
 r classical electron radius
 n electron density
 $J J^2(k)$ Bessel factor

$\Rightarrow$ high current (short bunch)

$\sigma_e < \rho/2$ σ_e energy spread
 $\Rightarrow$ small energy spread

Tentative TTF Timetable

