Two Colors and Photon Correlation Spectroscopy

F. Parmigiani,

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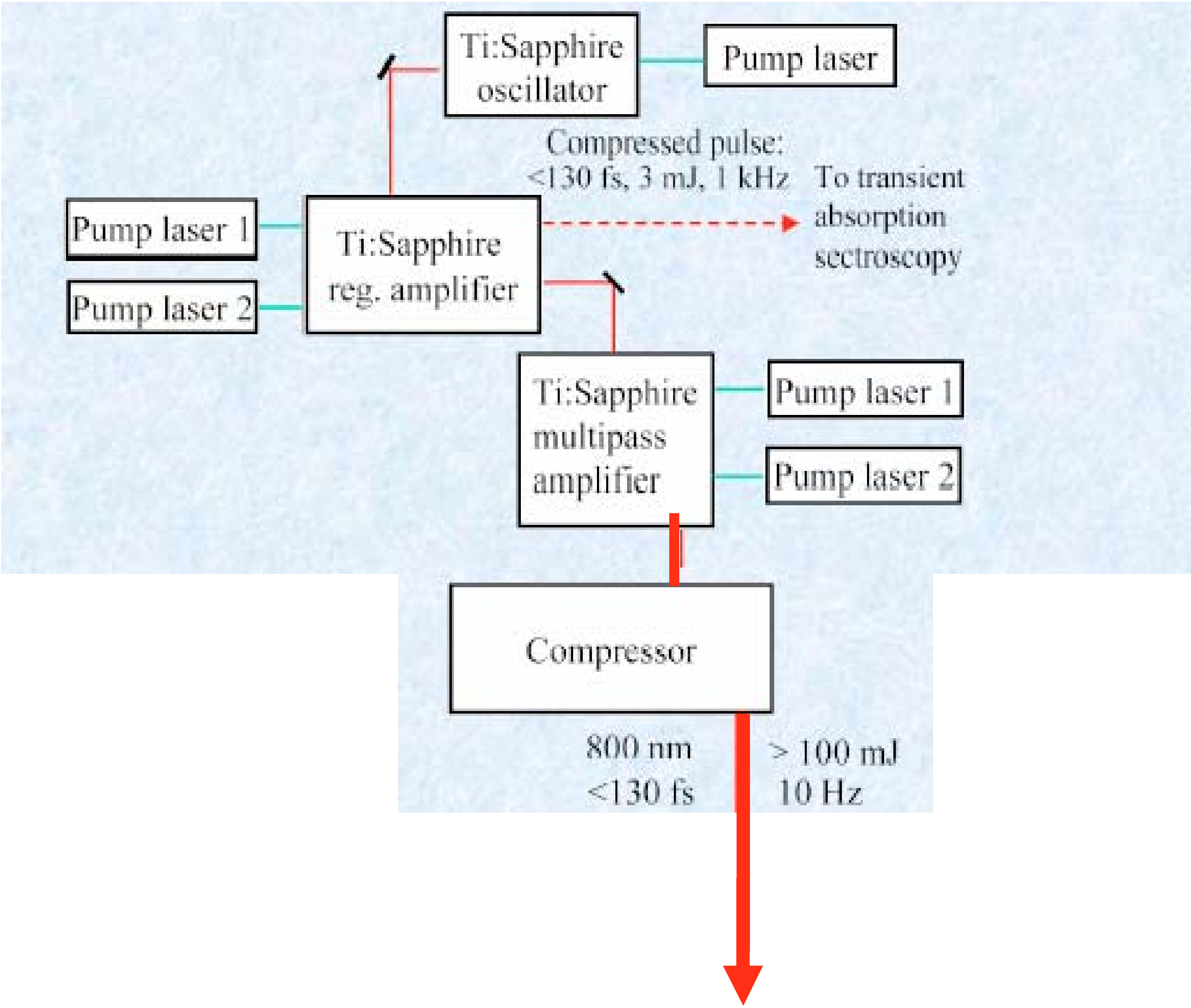
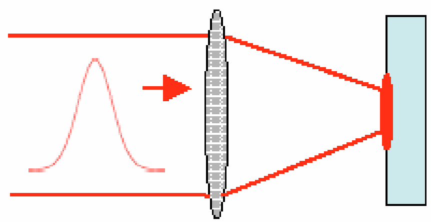
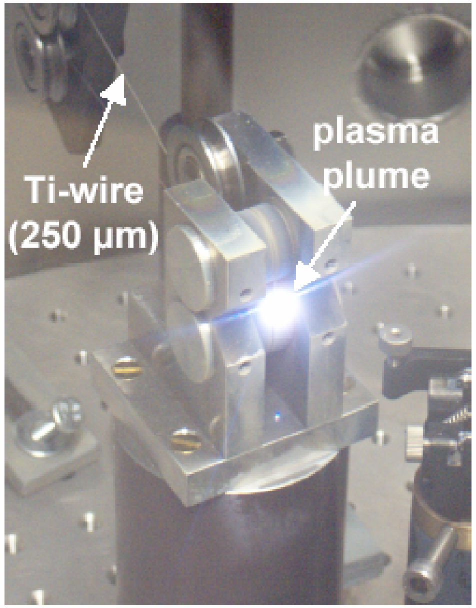
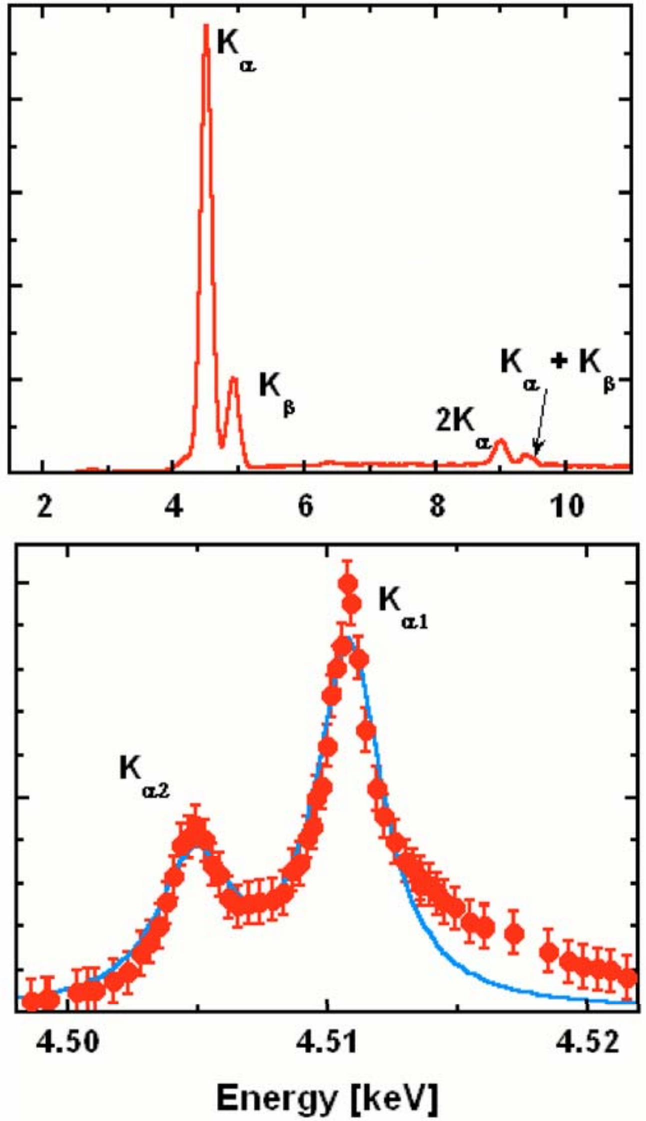
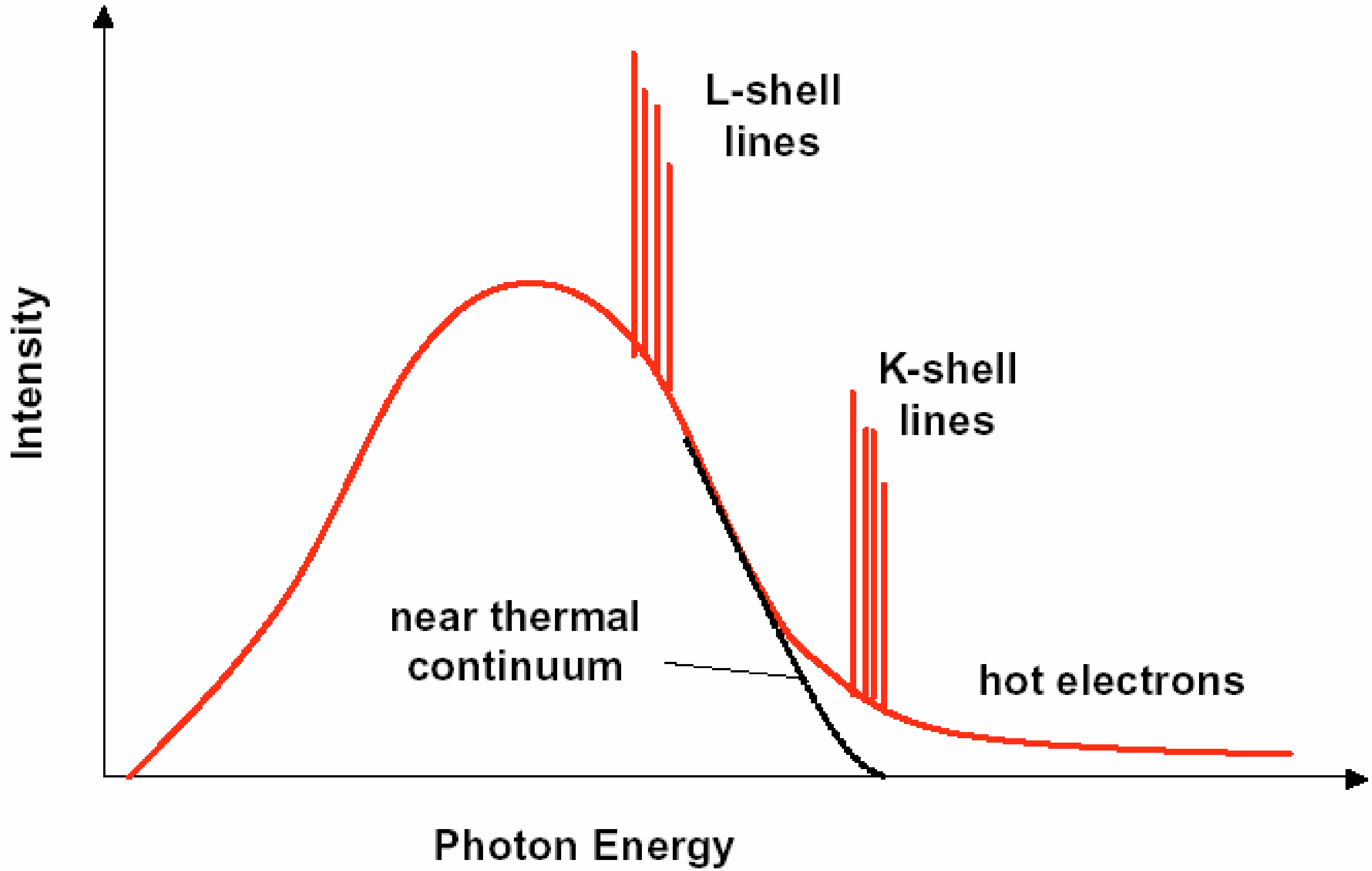

Ti:Sapphire oscillator
Pump laser
Compressed pulse:
<130 fs, 3 mJ, 1 kHz
To transient absorption sectroscopy
Pump laser 1
Pump laser 2
Ti:Sapphire reg. amplifier
Ti:Sapphire multipass amplifier
Pump laser 1
Pump laser 2
Compressor
800 nm
<130 fs
> 100 mJ
10 Hz

Klaus Sokolowski-Tinten
Institut für Experimentelle Physik









Klaus Sokolowski-Tinten

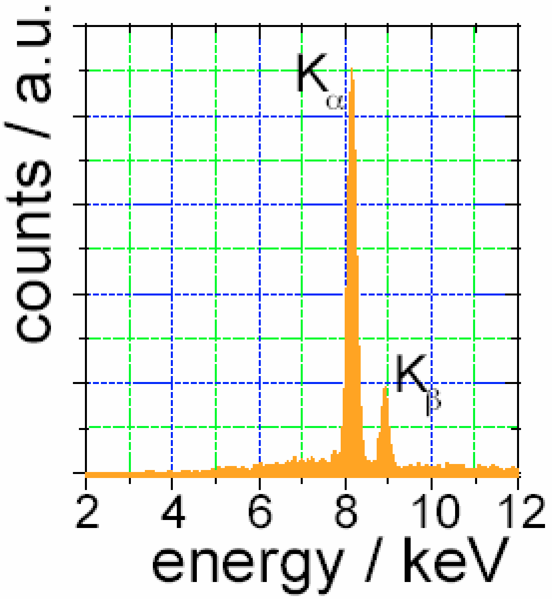
Institut für Experimentelle Physik

Max Born Institute
Berlin

Matias Bargheer,
N. Zhavoronkov, Y. Gritsai,
M. Wörner, T. Elsaesser

K_α line radiation:

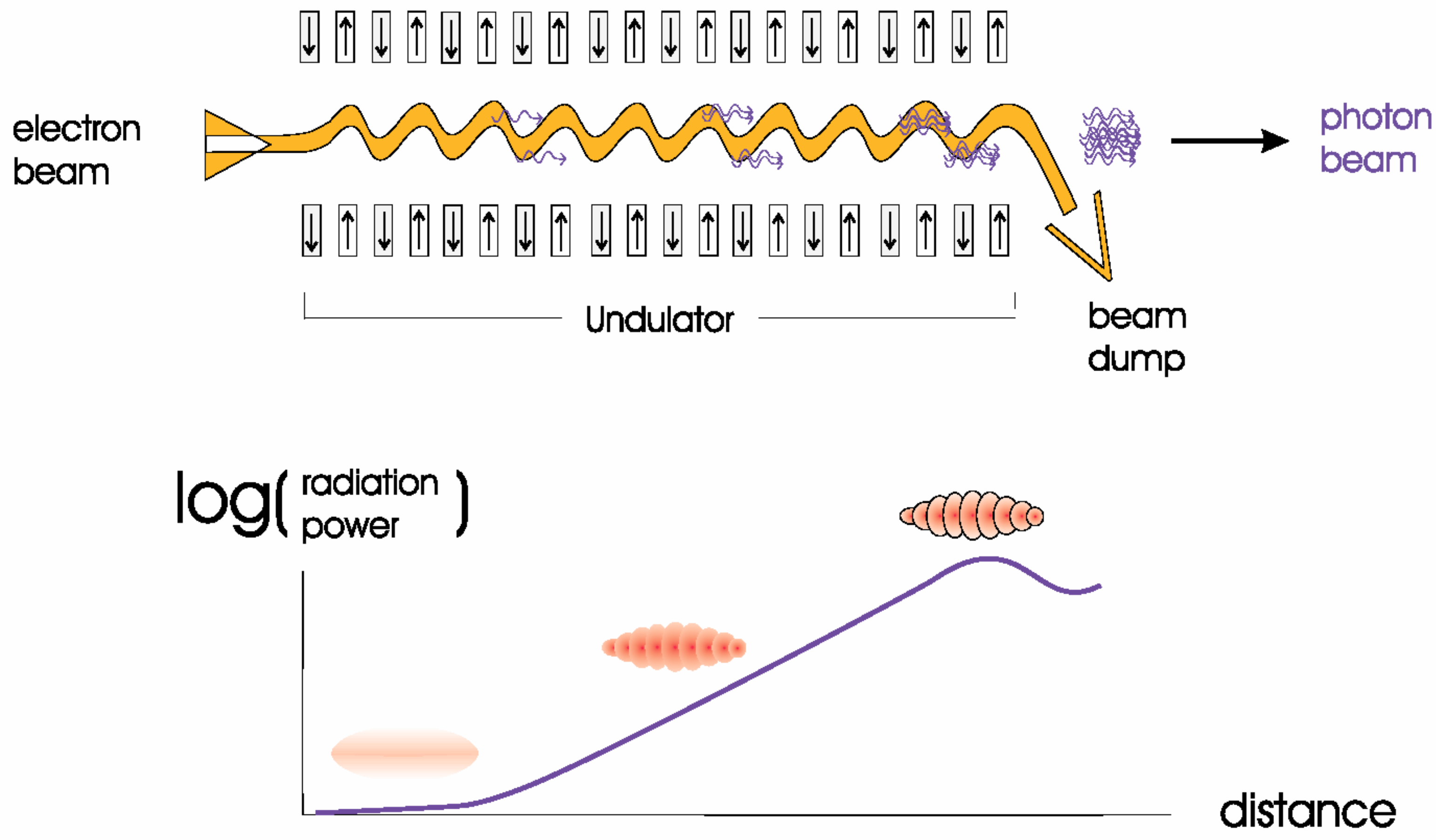
	K_α energy/ eV	K_α flux / 4π*s
Ga	9.2	4.5×10^{10}
Cu	8.2	3.9×10^{10}
Ni	7.5	6.7×10^{10}



- Plasma generated in 15 μm copper
- X-ray focus 15 μm
- Estimated pulse duration: 200 fs

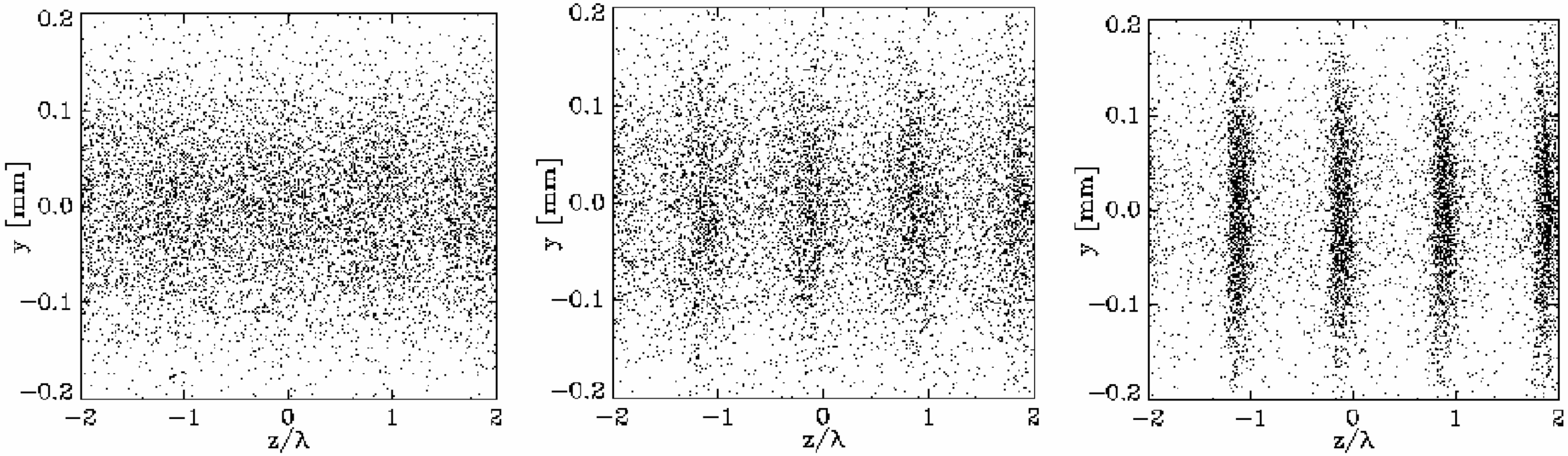
Brilliance = 4 x 10^7 / (mrad^2*mm^{2}s*0.1%BW)

According to specs	Flux on sample / s	Focus / μm
Multilayer mirror (Osmic)	1.4×10^6	30
HOPG reflector (IfG)	5×10^7	200


electron beam
photon beam
Undulator
beam dump
log(radiation power)
distance

***BACH** - **B**eamline for **A**dvanced di**CH**roism*

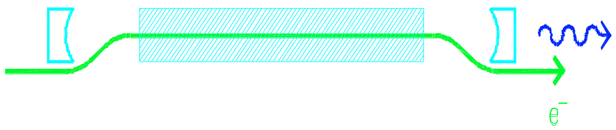
HE Undulator



y [mm]
z/λ
0.2
0.1
0.0
−0.1
−0.2
−2
−1
0
1
2

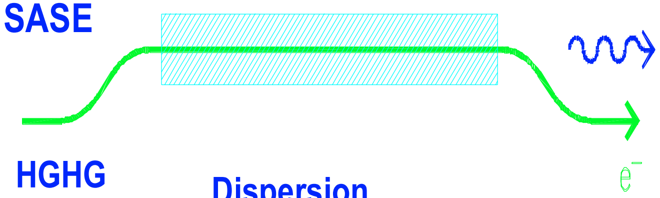
The BESSY Soft X-Ray SASE FEL (Free Electron Laser)

OSCILLATOR

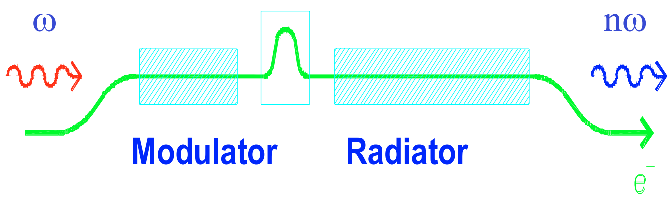


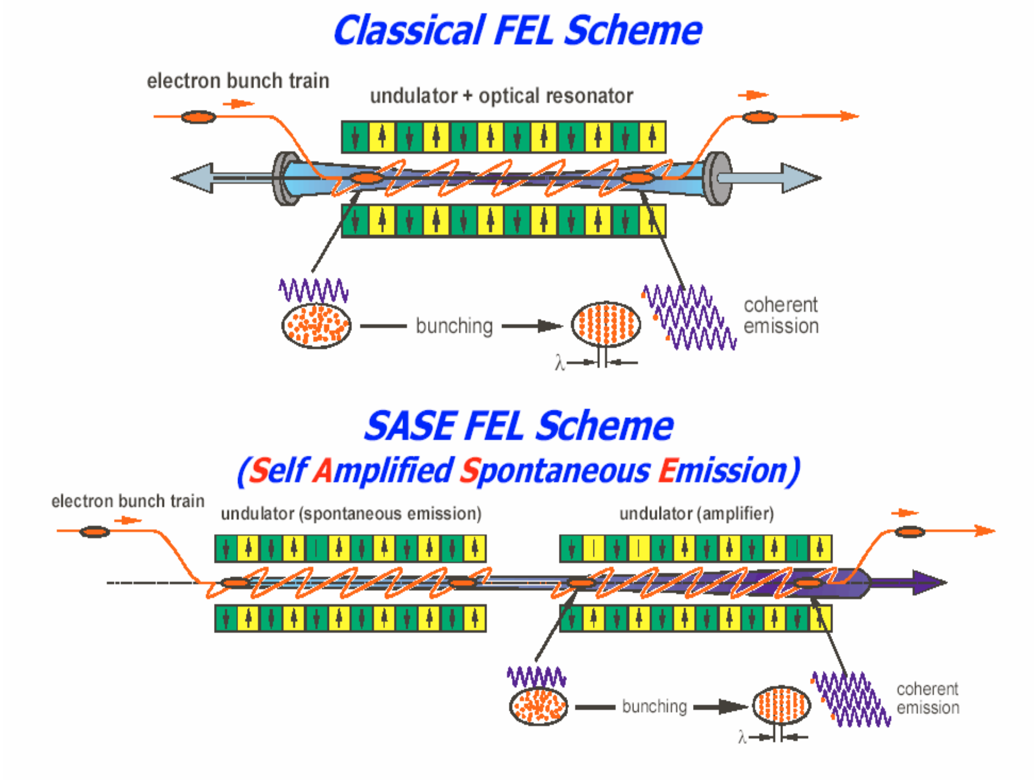
SINGLE PASS FEL

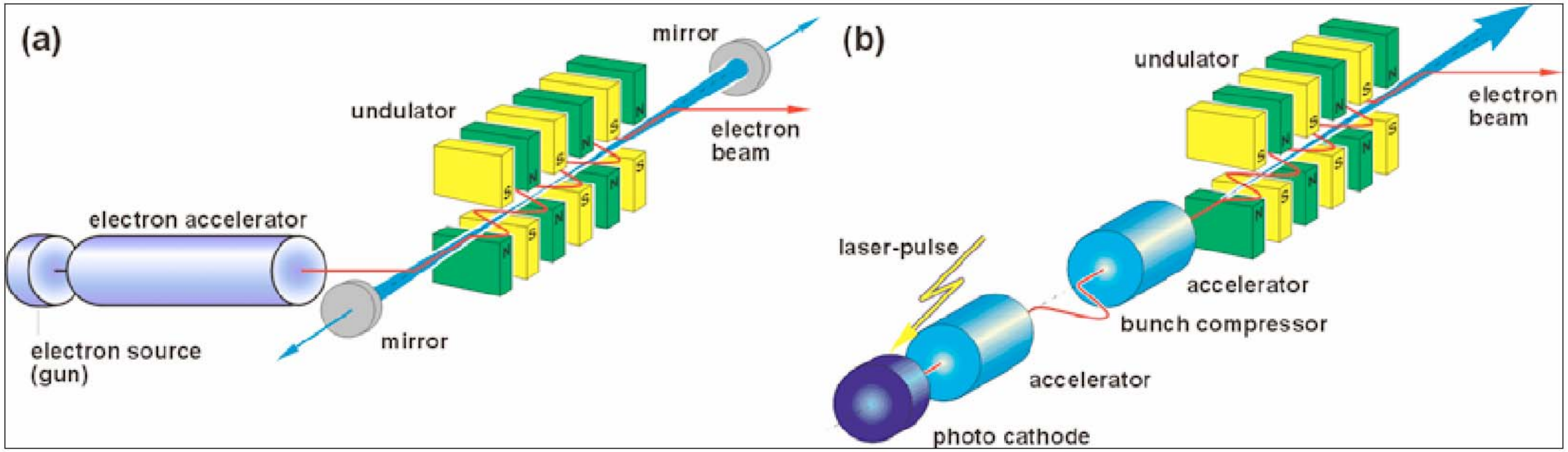
SASE

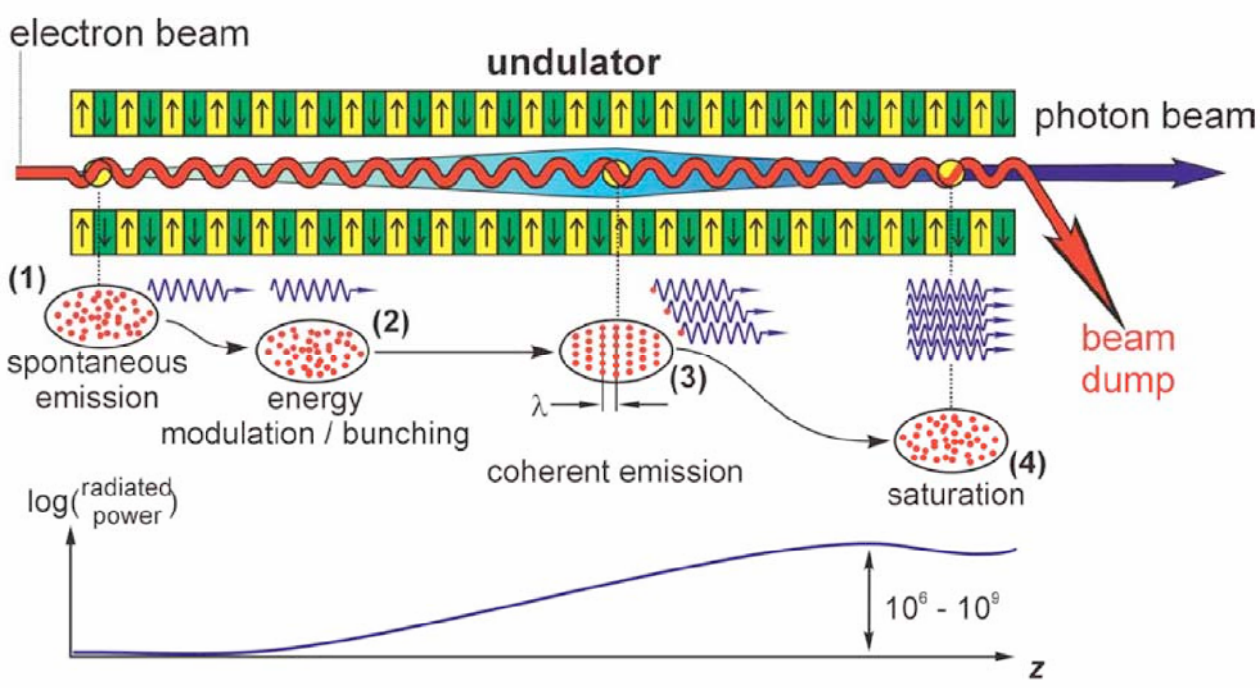


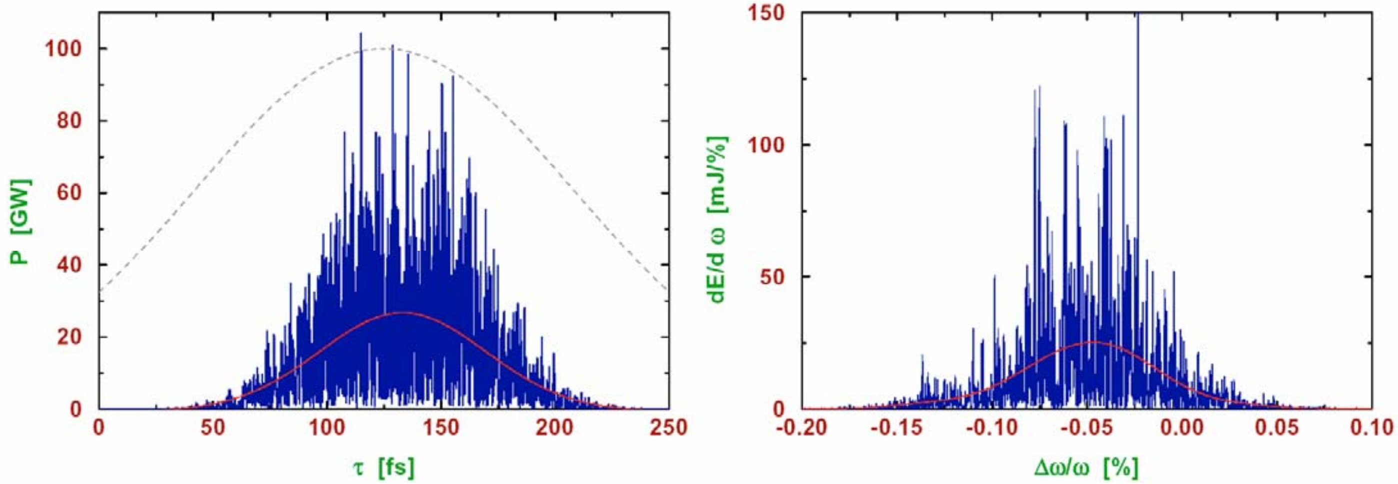
HGHG






(a)
mirror
undulator
electron
beam
electron accelerator
electron source
(gun)
mirror
(b)
undulator
electron
beam
laser-pulse
accelerator
bunch compressor
accelerator
photo cathode


electron beam
undulator
photon beam
(1)
spontaneous
emission
(2)
energy
modulation / bunching
(3)
λ
coherent emission
(4)
saturation
beam
dump
log(radiated power)
10^6 - 10^9
z



	Units	SASE 1
Wavelength*	Å	1–5
Peak power	GW	37
Average power	W	210
Photon beam size (FWHM)**	μm	100
Photon beam divergence (FWHM)***	μrad	0.8
Bandwidth (FWHM)	%	0.08
Coherence time	fs	0.3
Pulse duration (FWHM)	fs	100
Min. pulse separation****	ns	93
Max. number of pulses per train****	#	11500
Repetition rate****	Hz	5
Number of photons per pulse	#	1.8×10^{12}
Average flux of photons	#/sec	1.0×10^{17}
Peak brilliance	B*****	8.7×10^{33}
Average brilliance	B*****	4.9×10^{25}

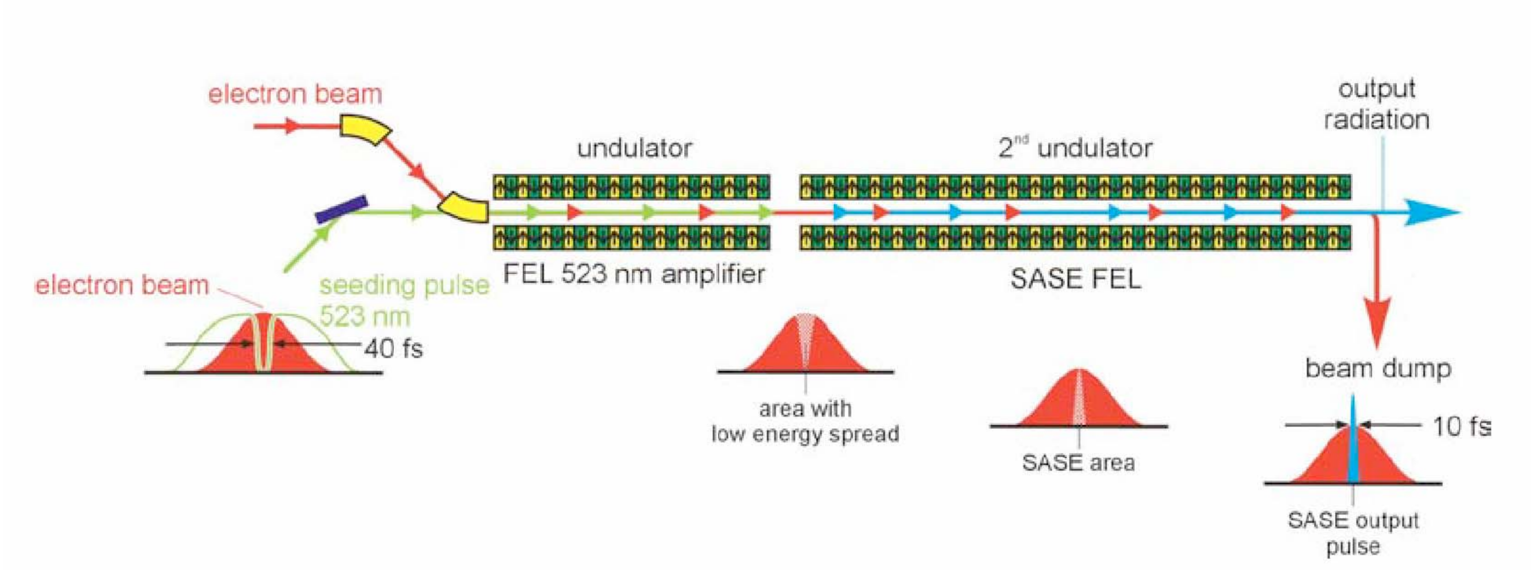
*Parameters are given for the shortest wavelength.

** Value at the exit of the undulator.

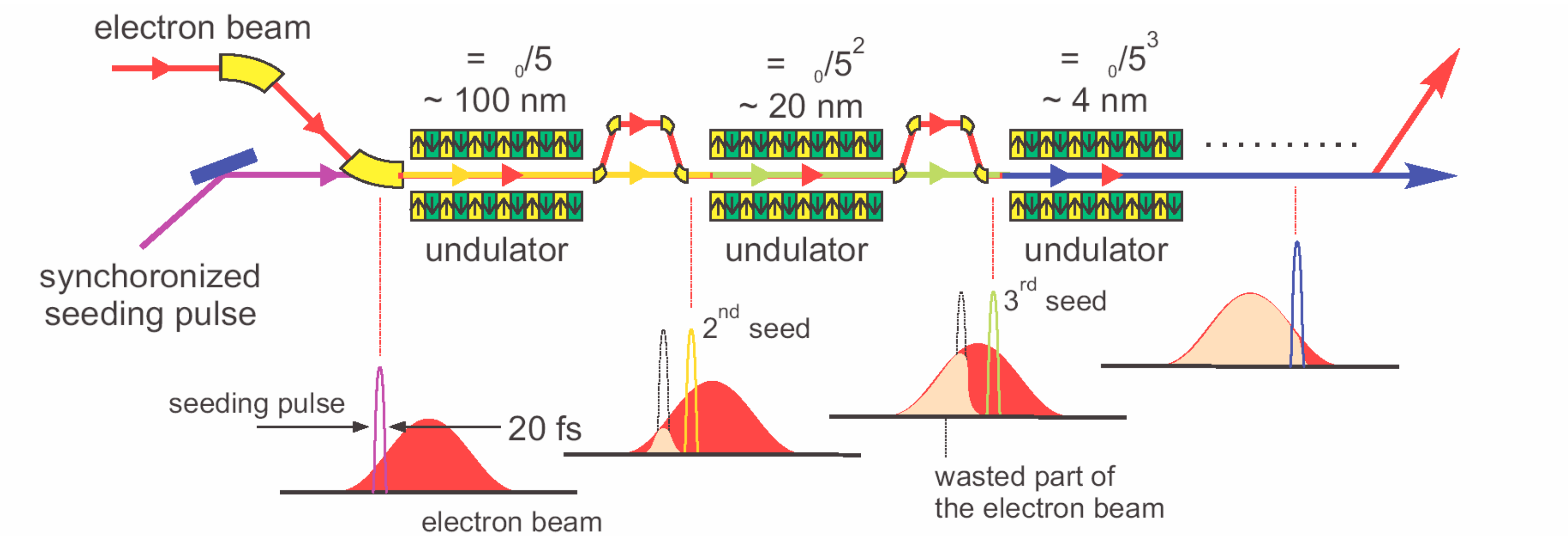
*** Far field divergence.

**** Values determined by the time structure of the electron beam in the accelerator. The average parameters for the SASE-1 FEL are given for the ultimate case when only this beamline is in operation.

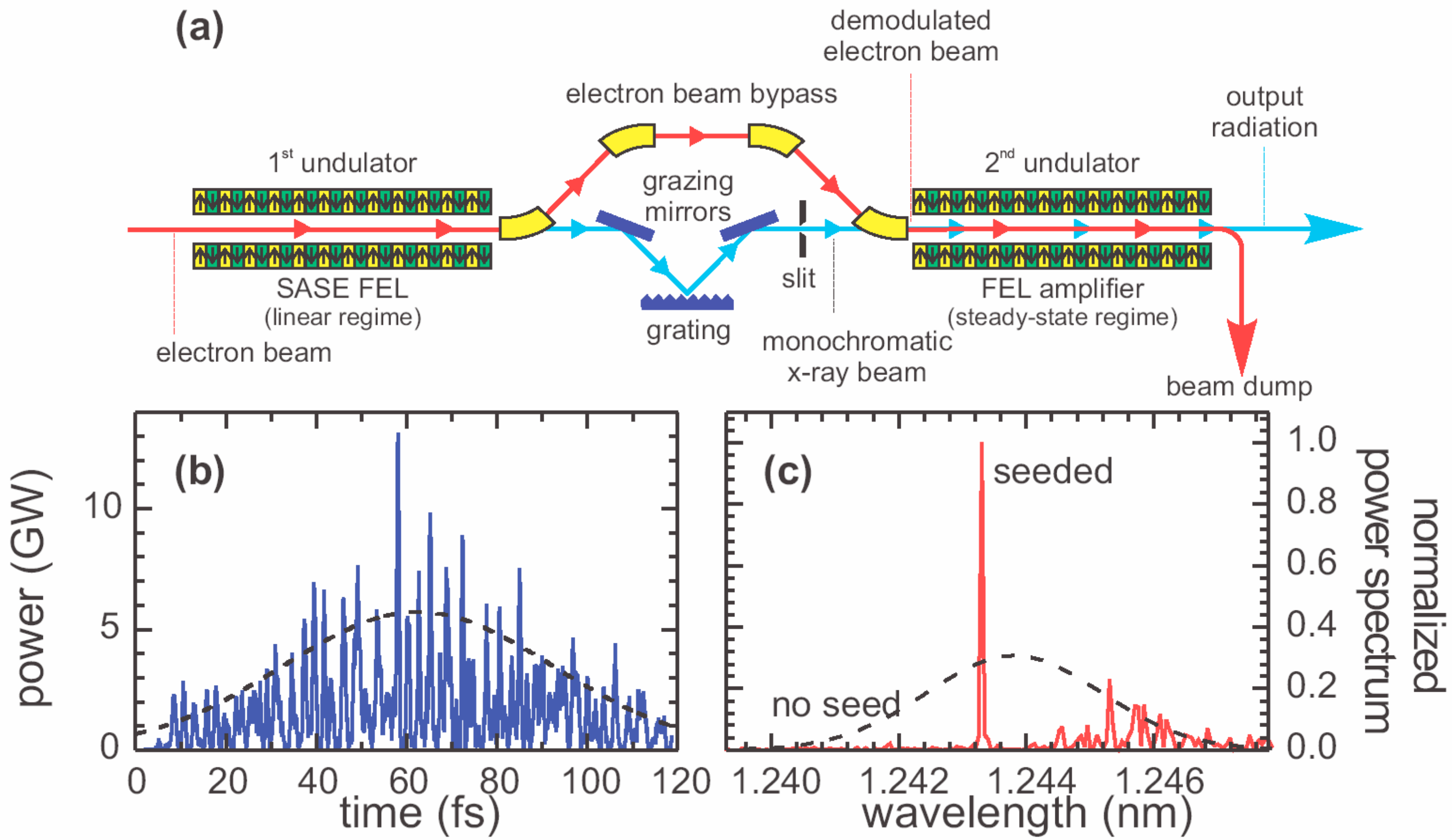
***** In units of photons/(sec · mrad^2 · mm^2 · 0.1 % bandwidth).



electron beam
undulator
2nd undulator
output radiation
electron beam
seeding pulse
523 nm
40 fs
FEL 523 nm amplifier
SASE FEL
beam dump
area with
low energy spread
SASE area
10 fs
SASE output
pulse



electron beam
= $_0$/5
~ 100 nm
= $_0$/5^2
~ 20 nm
= $_0$/5^3
~ 4 nm
undulator
undulator
undulator
synchoronized
seeding pulse
2nd seed
3rd seed
seeding pulse
20 fs
electron beam
wasted part of
the electron beam

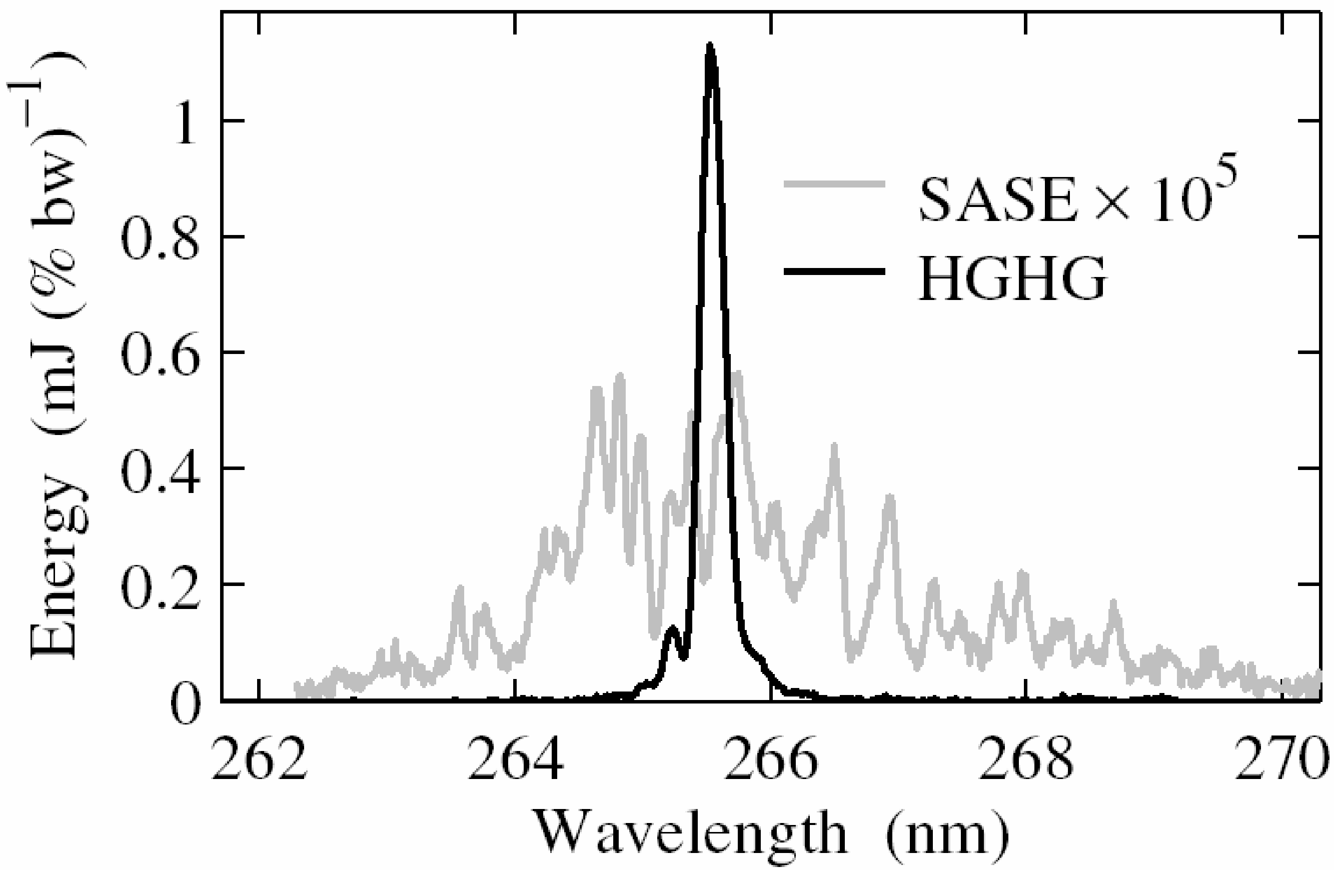


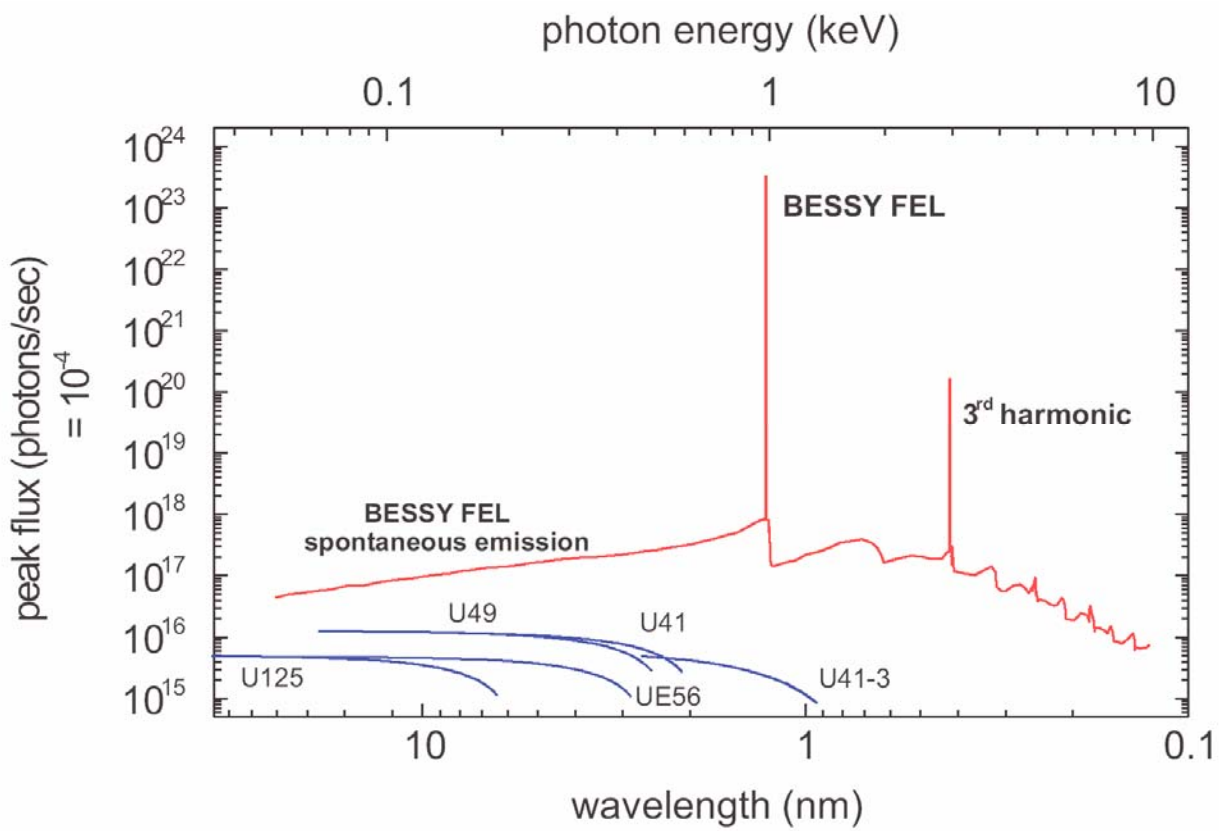
Top: Basic scheme of a two-stage FEL [16] providing full longitudinal and transverse coherent light, see text for details. Bottom: GENESIS simulation of the two-stage FEL employing a 3 kW seed in the second undulator.

First Ultraviolet High-Gain Harmonic-Generation Free-Electron Laser

L. H. Yu,* L. DiMauro, A. Doyuran, W. S. Graves,† E. D. Johnson, R. Heese, S. Krinsky, H. Loos, J. B. Murphy, G. Rakowsky, J. Rose, T. Shaftan, B. Sheehy, J. Skaritka, X. J. Wang, and Z. Wu
National Synchrotron Light Source, Brookhaven National Laboratory, Upton, New York 11973, USA
(Received 25 March 2003; published 14 August 2003)

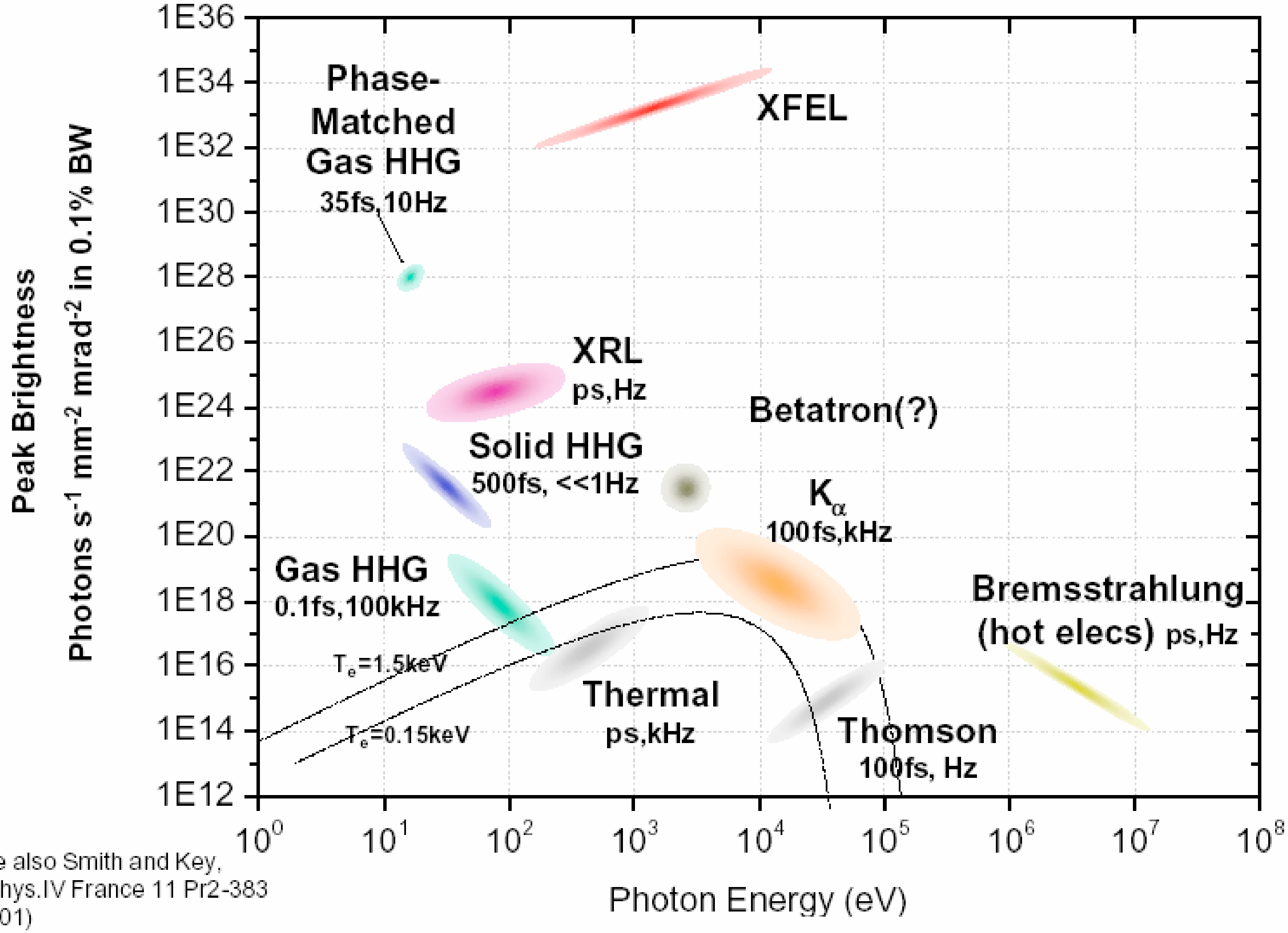
We report the first experimental results on a high-gain harmonic-generation (HGHG) free-electron laser (FEL) operating in the ultraviolet. An 800 nm seed from a Ti:sapphire laser has been used to produce saturated amplified radiation at the 266 nm third harmonic. The results confirm the predictions for HGHG FEL operation: stable central wavelength, narrow bandwidth, and small pulse-energy fluctuation.





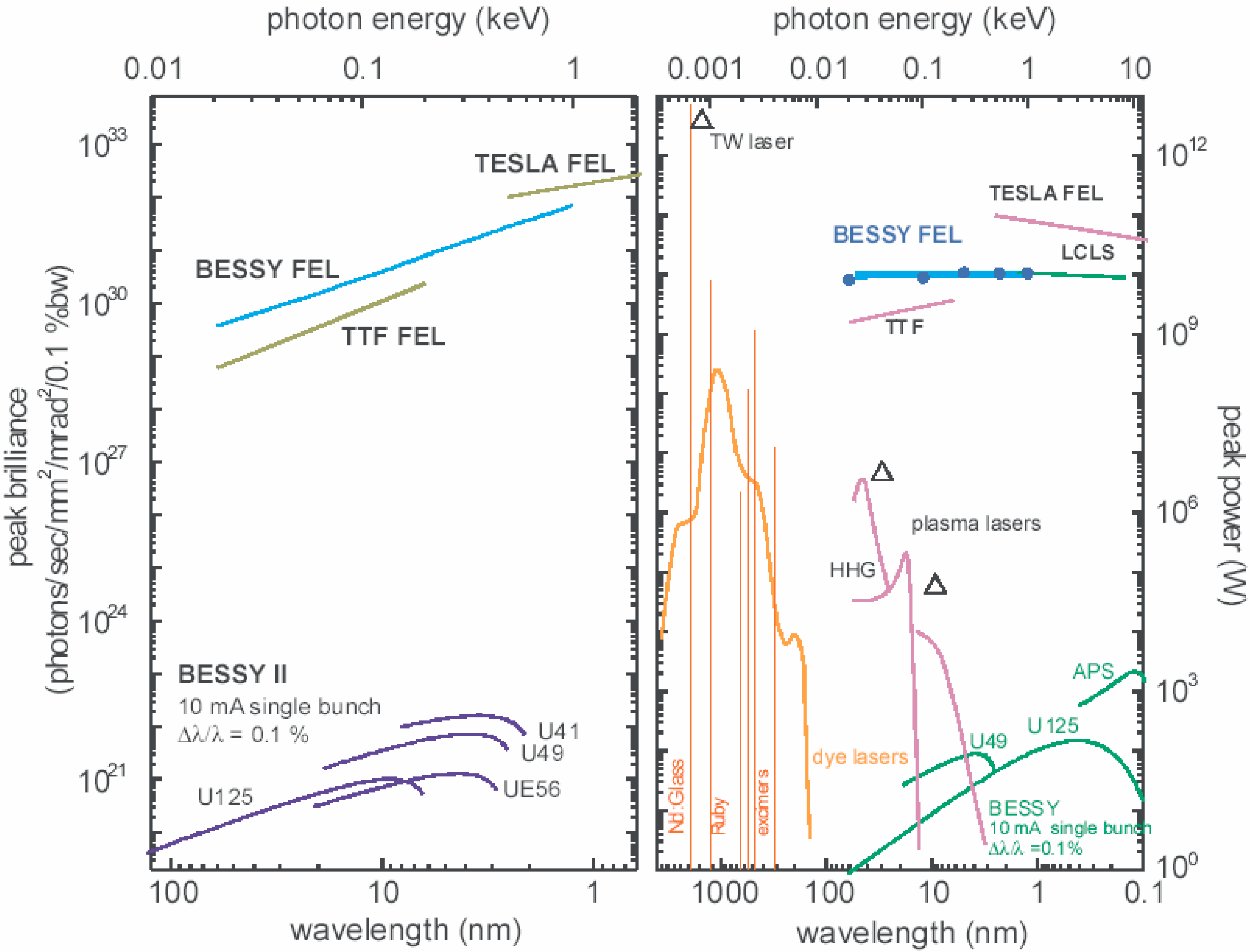
Spectrum of the BESSY SASE-FEL for a lasing photon energy of ħω = 1 keV compared to the BESSY II performance. BESSY II: single bunch operation with 10 mA of average beam current at E = 1.7 GeV. BESSY SASE-FEL: I = 5 kA, E = 2.25 GeV and a planar undulator with λ_u = 2.75 cm and N = 1450 periods. Spectra are calculated with a transmission efficiency of the monochromator of 5%.

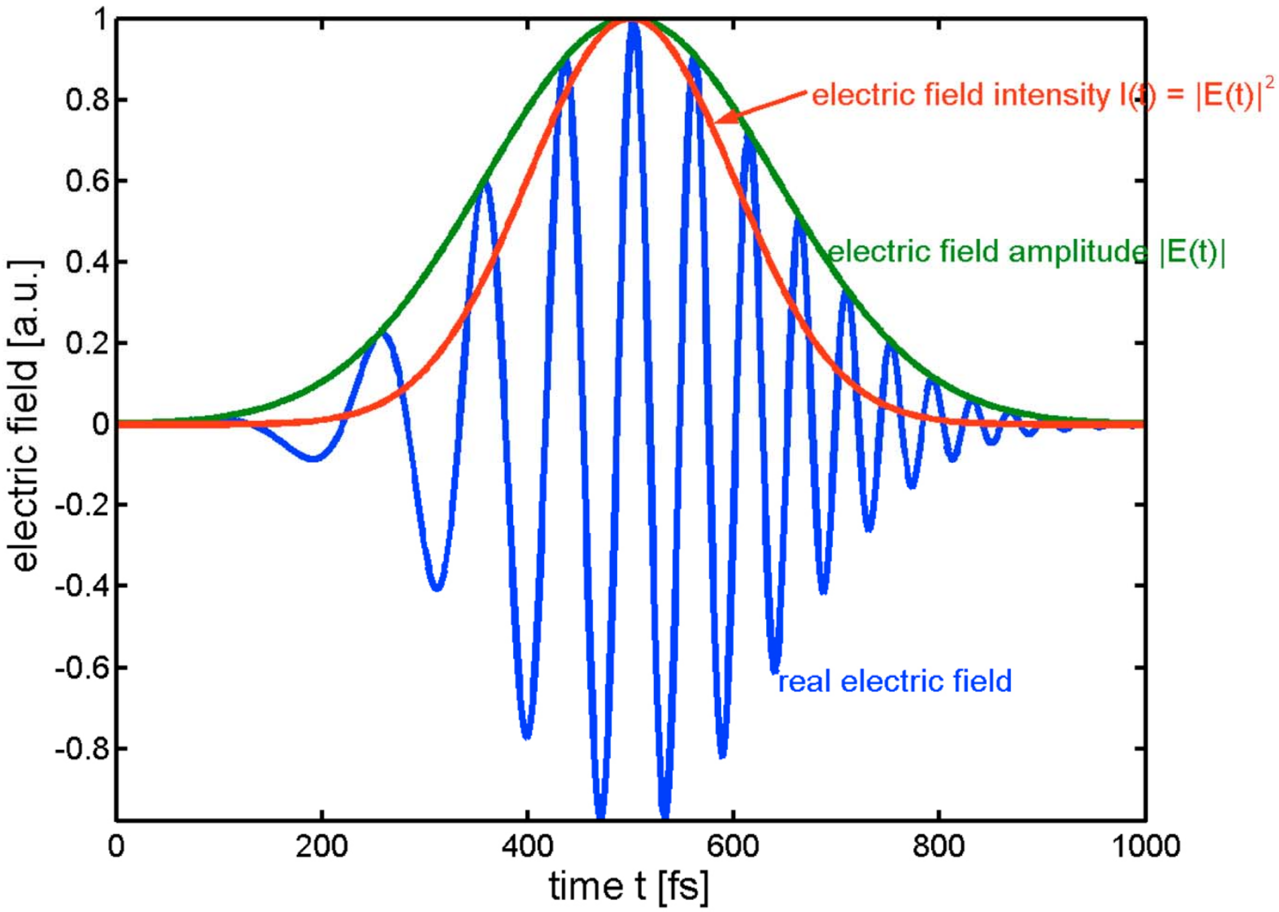
Peak Brightness Comparison



See also Smith and Key,
J.Phys.IV France 11 Pr2-383
(2001)

Performance

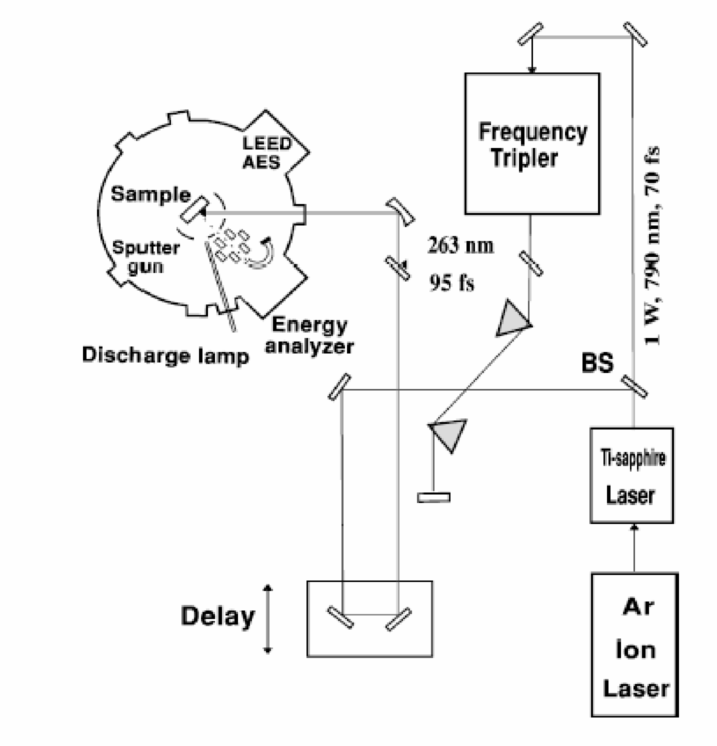


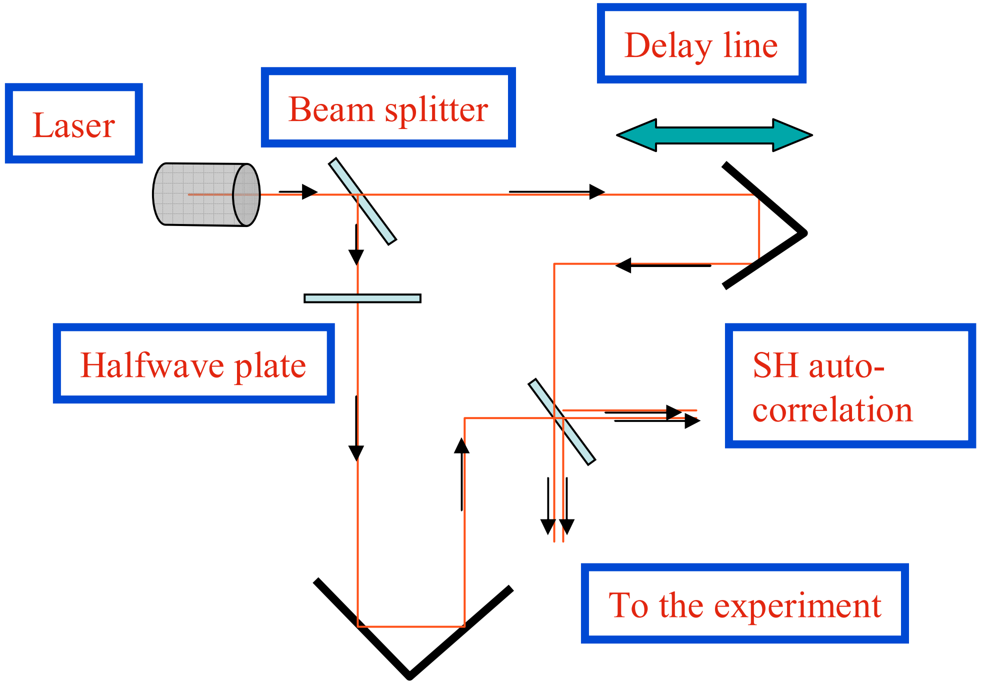


An ultrashort pulse of light in the time domain. In this figure, the amplitude and intensity are Gaussian functions. The phase function is quadratic, resulting in an instantaneous frequency sweep sometimes called *chirp*, in analogy to the sound of some birds.

Time structure

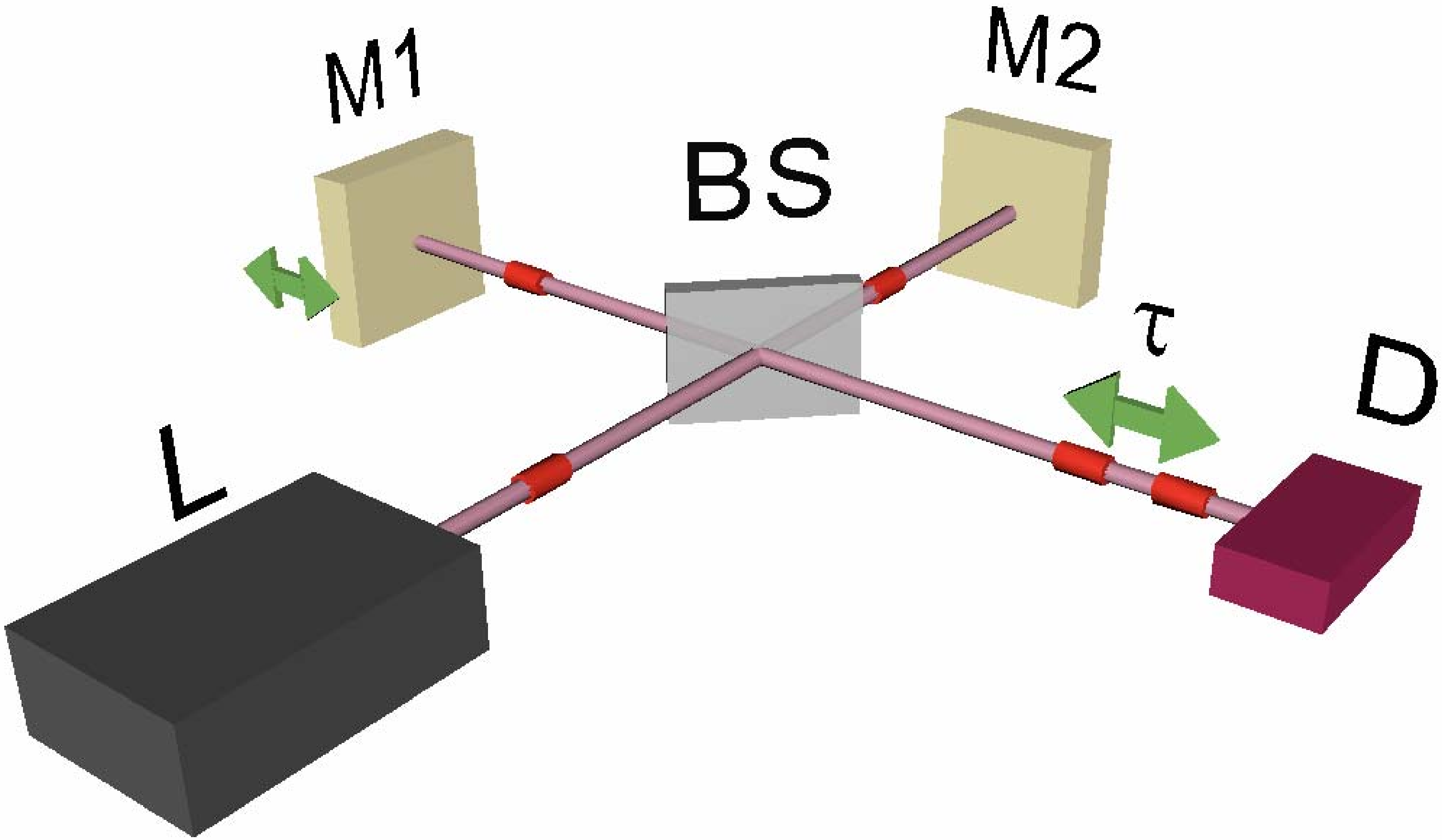
Pump - Probe setup



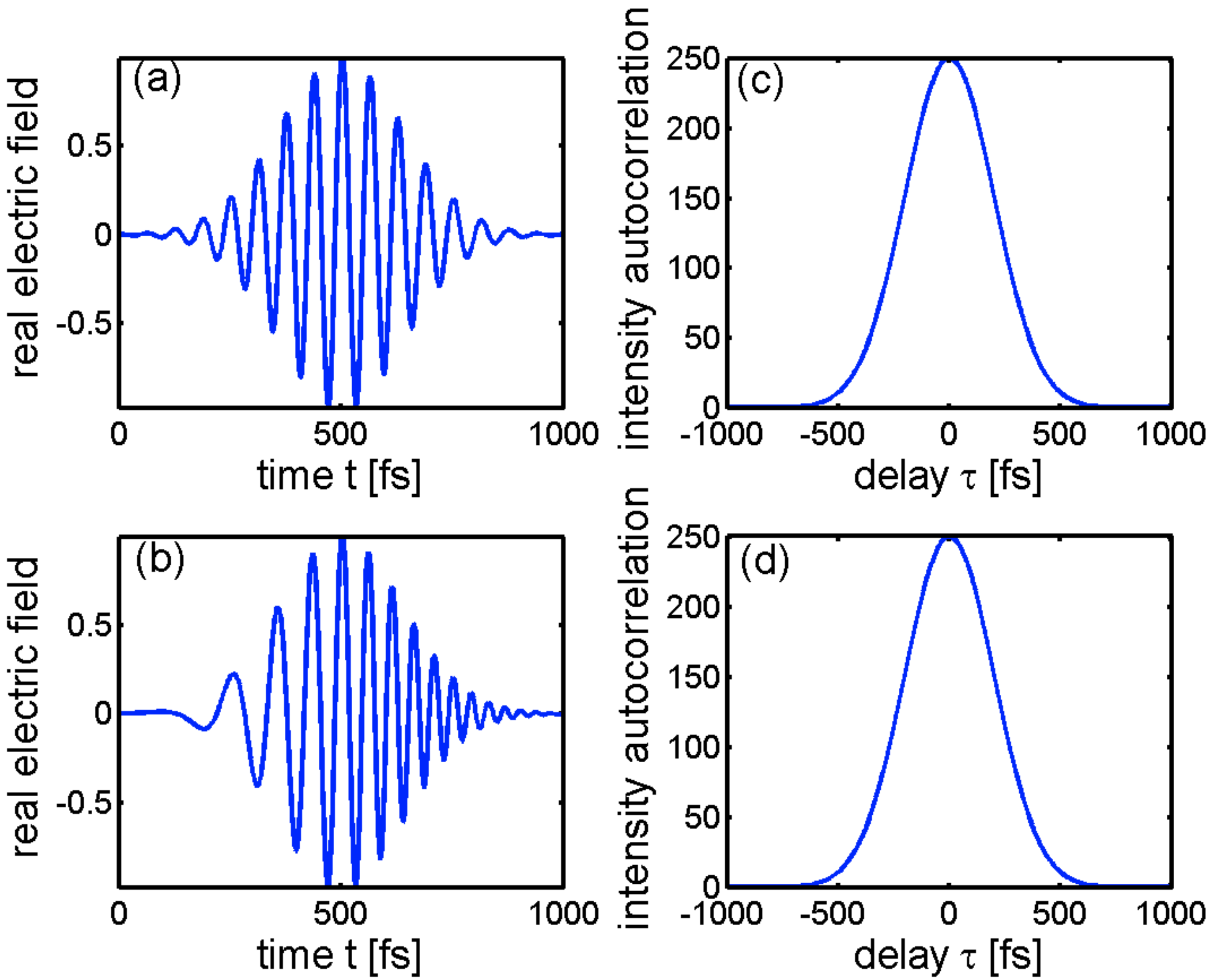


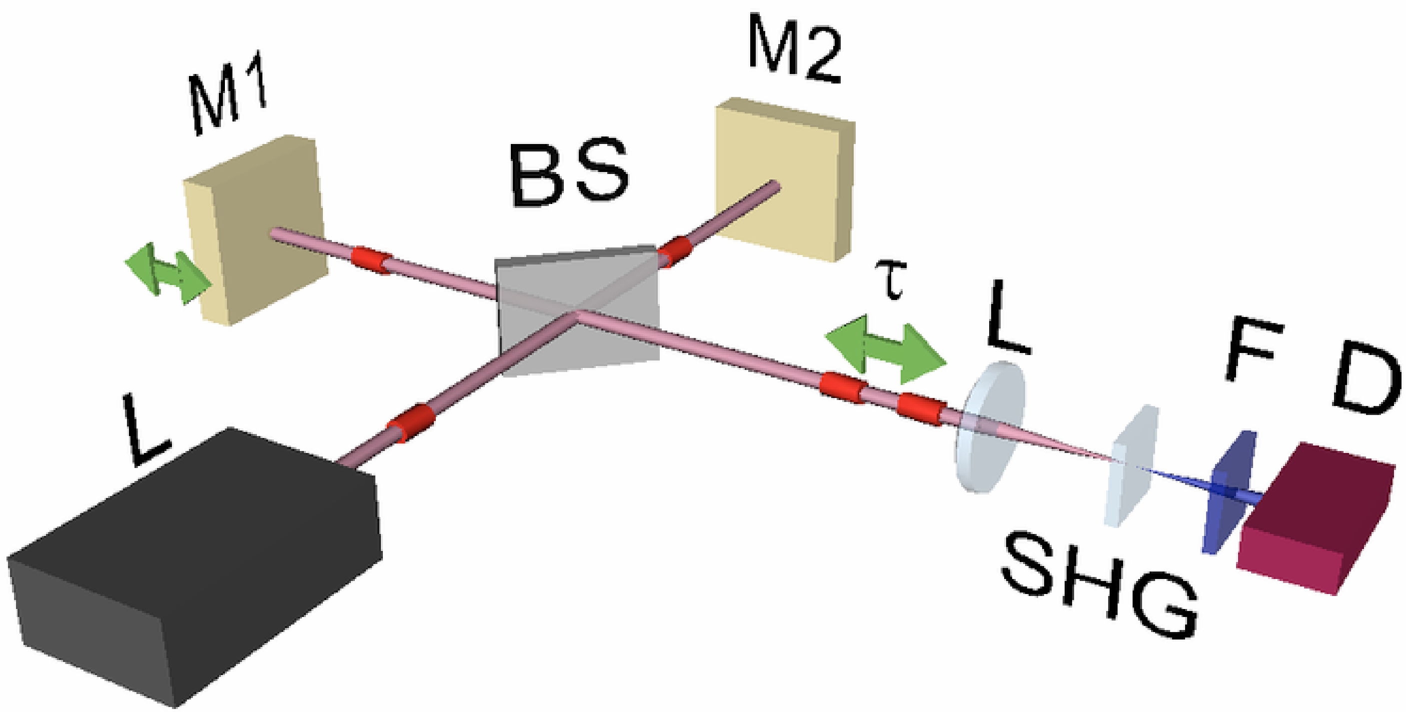
$$U_e(\tau) \propto \int_{-\infty}^{\infty} I_X(t) I_{IR}(t-\tau) dt$$

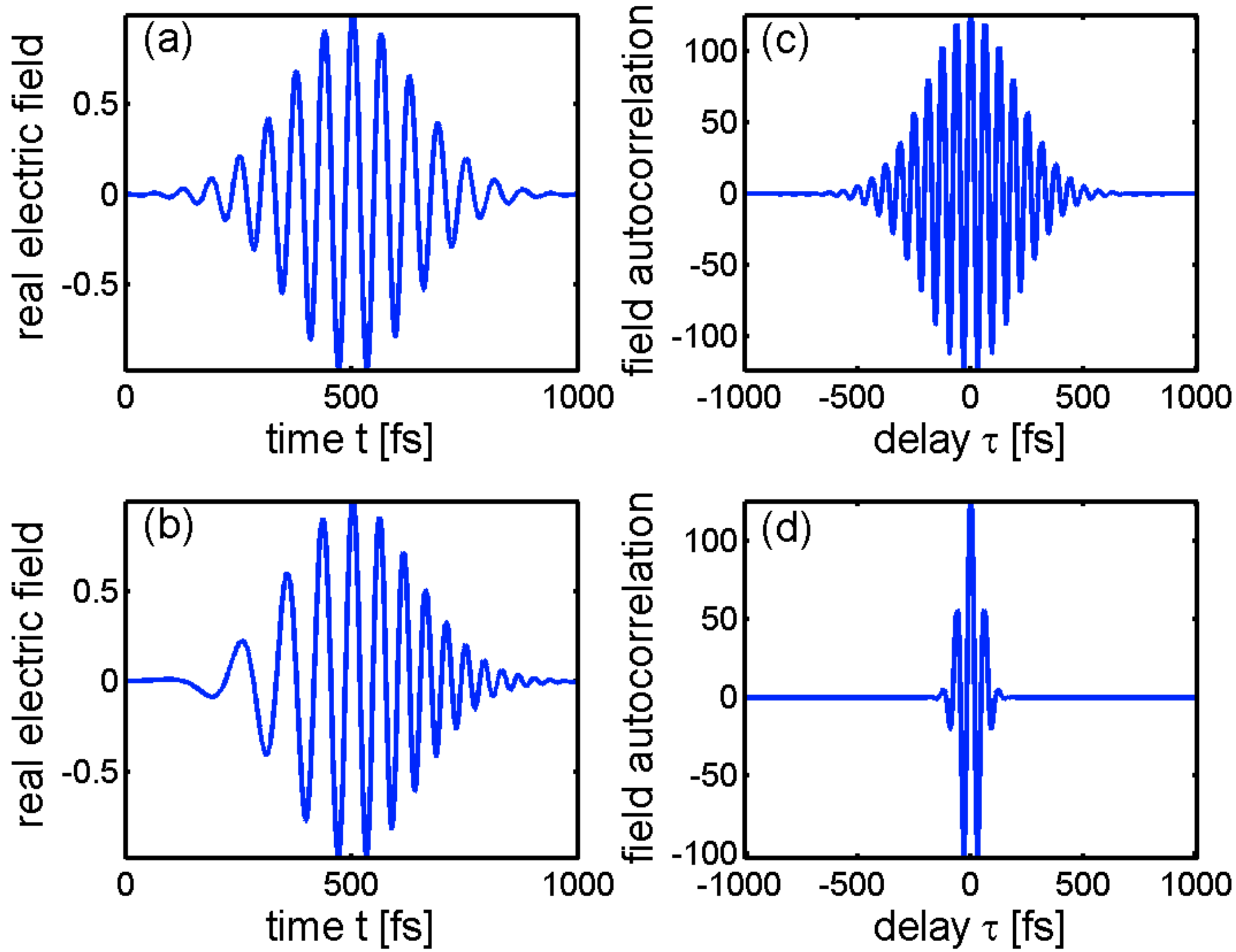
Mach Zehnder type interferometer



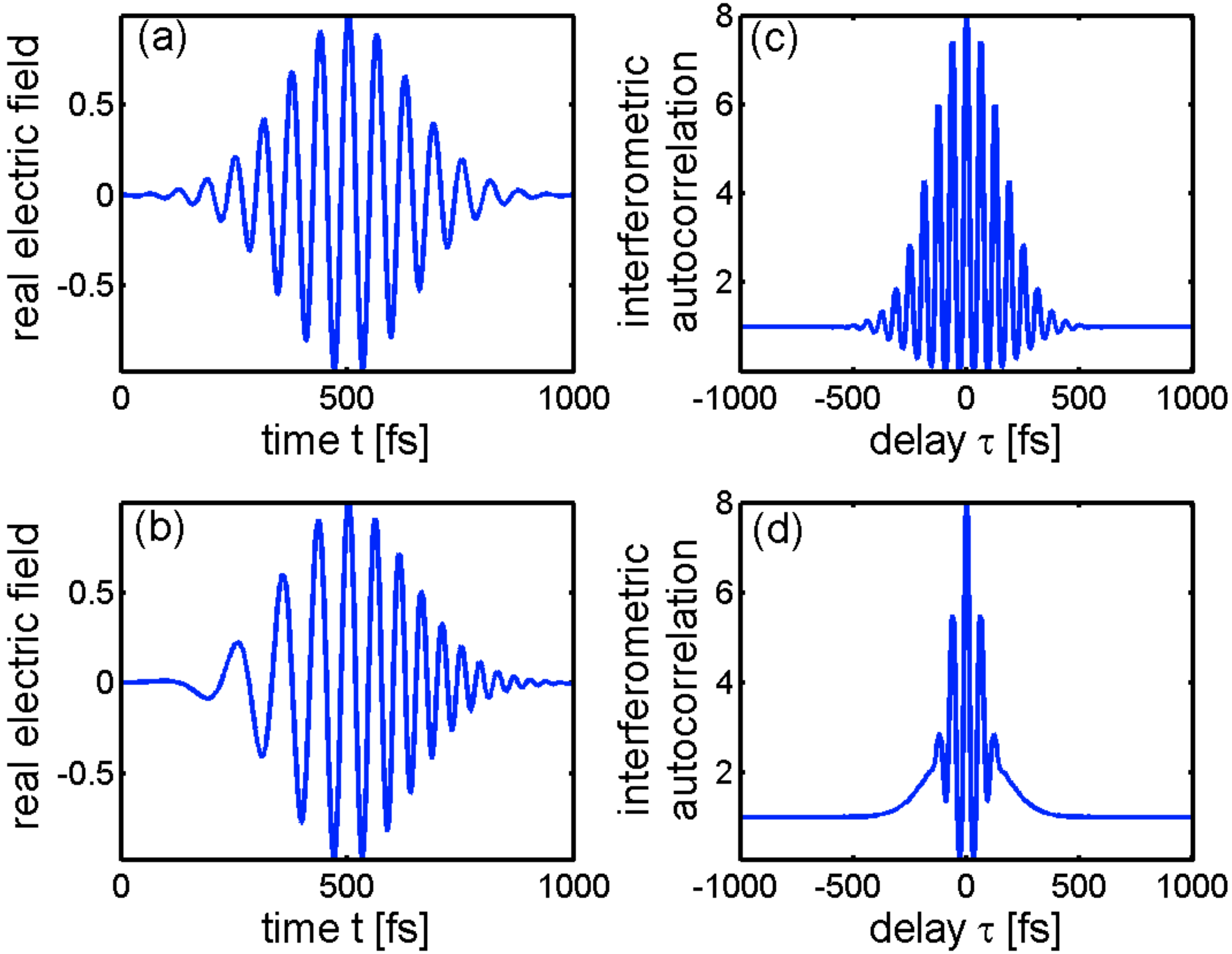
M1
M2
BS
τ
D
L


(a)
(b)
(c)
(d)
real electric field
time t [fs]
intensity autocorrelation
delay τ [fs]
0.5
0
-0.5
0
500
1000
250
200
150
100
50
-1000
-500


M1
M2
BS
τ
L
F
D
L
SHG



(a)
real electric field
0.5
0
-0.5
0
500
1000
time t [fs]
(c)
field autocorrelation
100
50
0
-50
-100
-1000
-500
0
500
1000
delay τ [fs]
(b)
real electric field
0.5
0
-0.5
0
500
1000
time t [fs]
(d)
field autocorrelation
100
50
0
-50
-100
-1000
-500
0
500
1000
delay τ [fs]


(a)
(b)
(c)
(d)
real electric field
time t [fs]
interferometric autocorrelation
delay τ [fs]
0.5
0
-0.5
500
1000
8
6
4
2
-1000
-500

Brilliance → Microscopy

- X-ray microscopy
- X-ray dichroic microscopy

Coherence → X-ray scattering

- X-ray elastic scattering (statistical optics)
- X-ray FT interferometry

Time structure → Pump-Probe

- Time resolved core level spectroscopy
- Time resolve spectroscopy zooming in the momentum space
- TR X-ray diffraction
- Dynamics of the phase transitions

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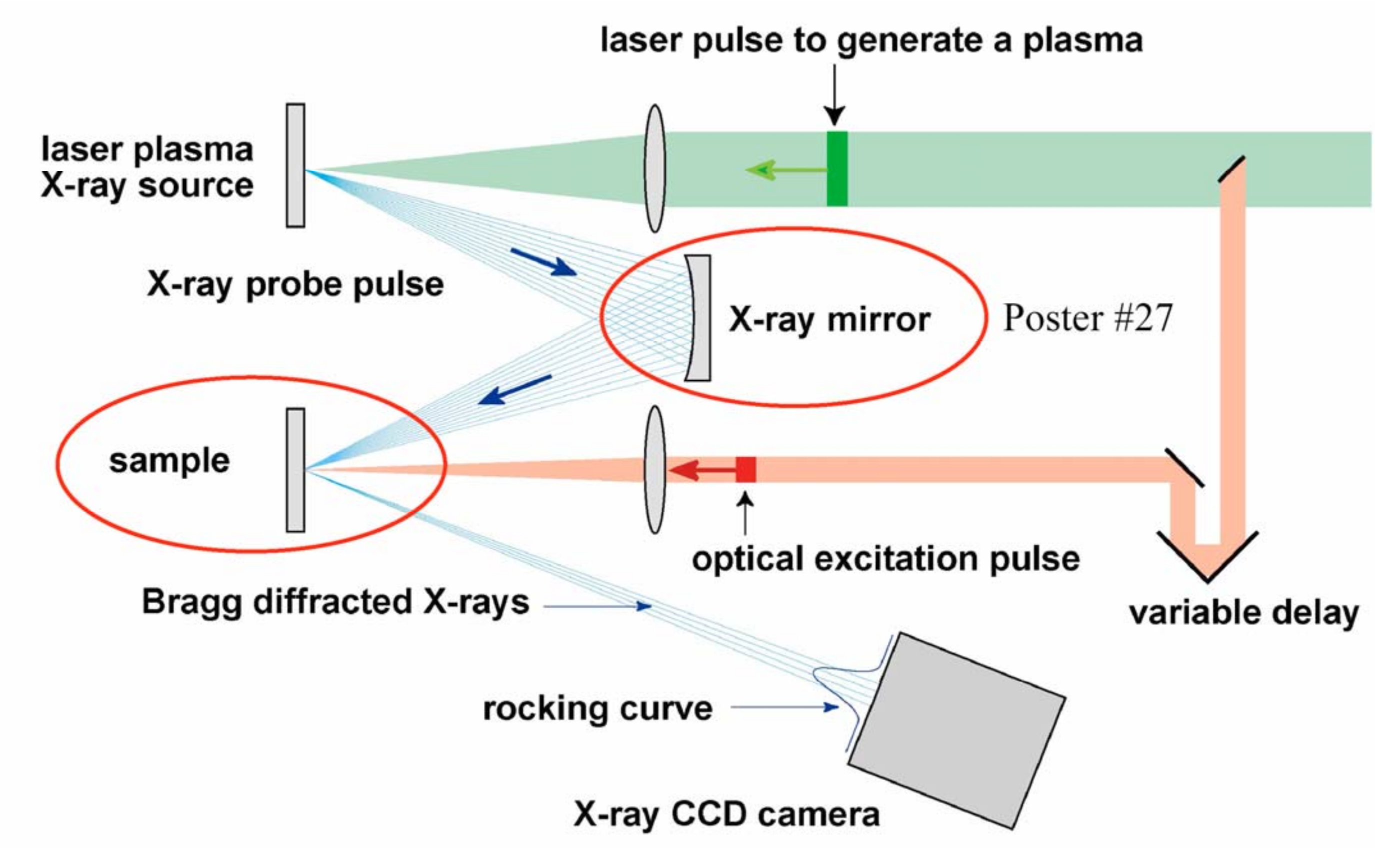
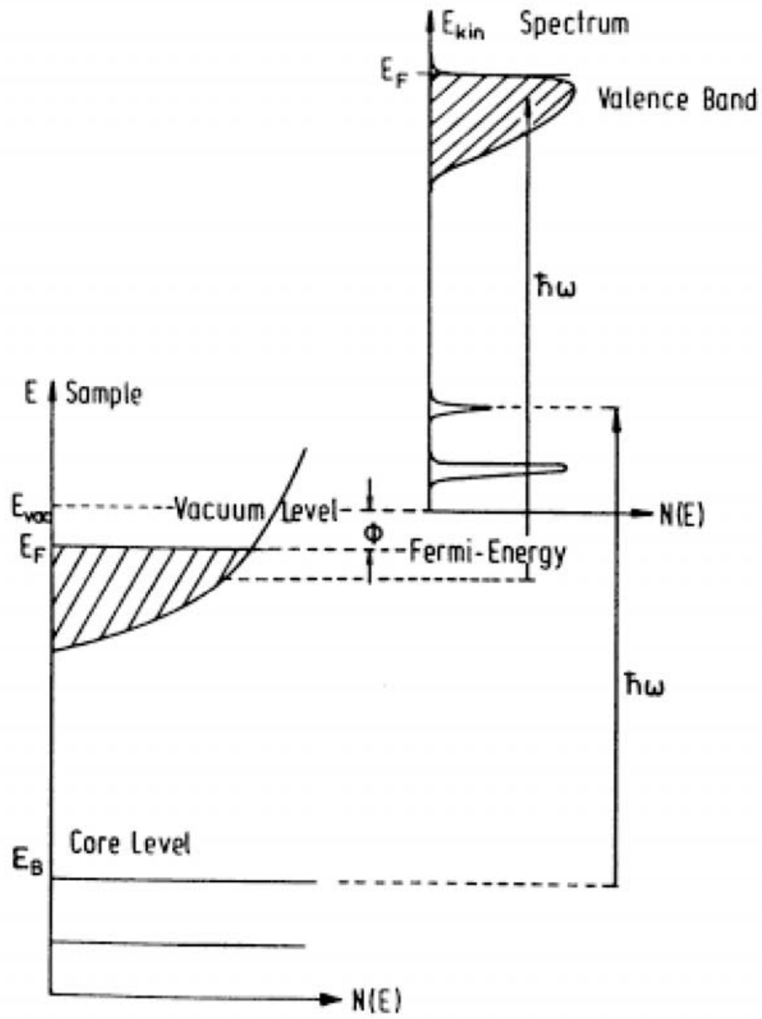
Institut für Experimentelle Physik





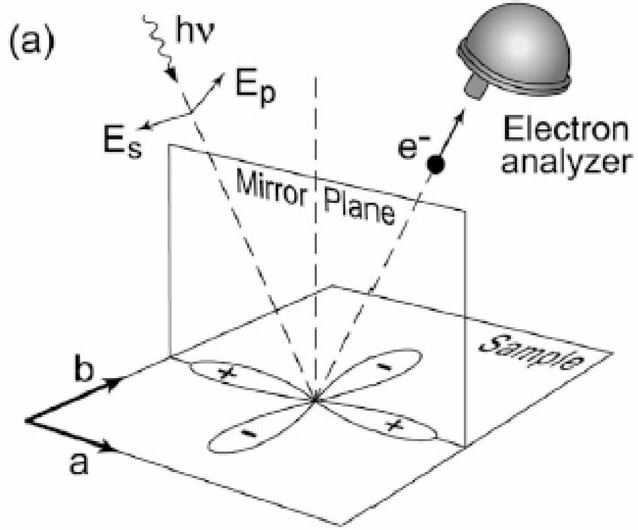
$$E_{kin} = \hbar\omega - \Phi \; - \left| E_B \right|$$

Measured Kinetic Energy

Measureed Photon Energy

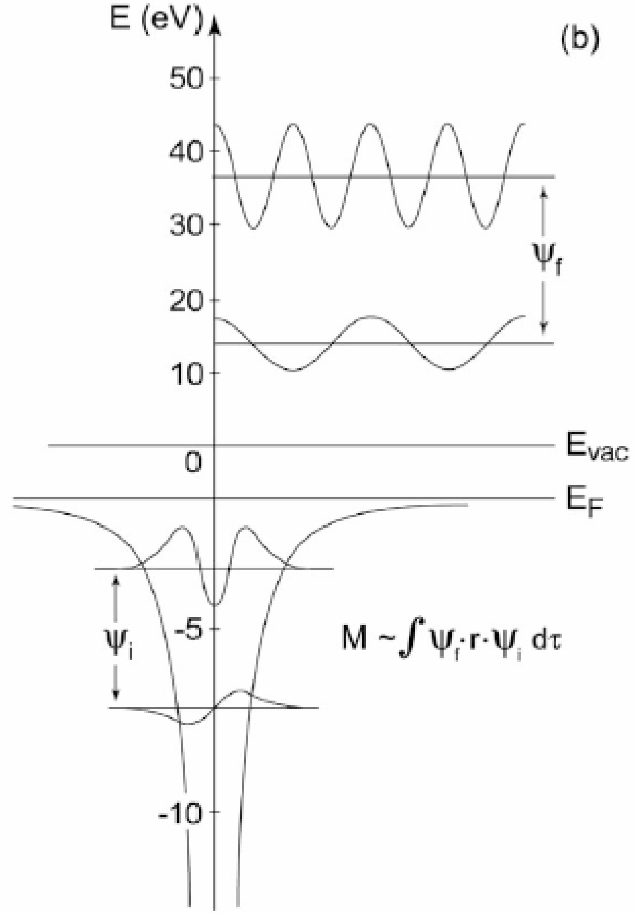
Measured Work Function

Electron Binding Energy

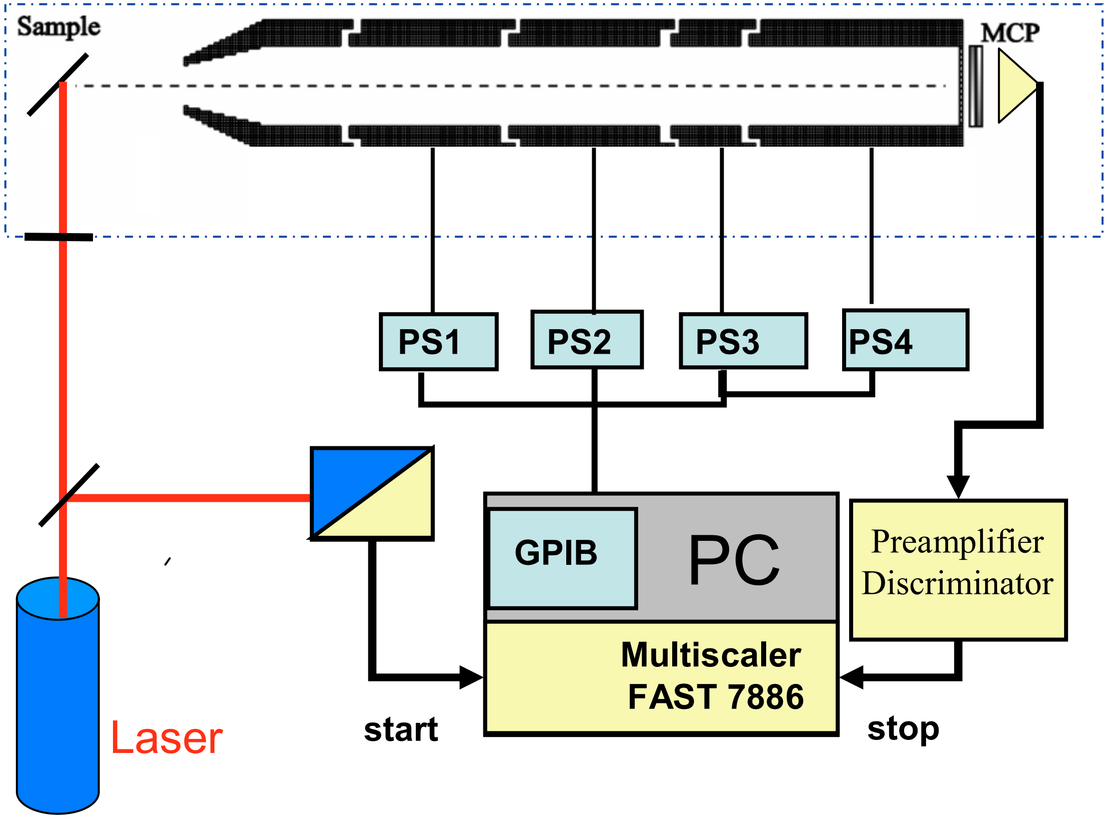


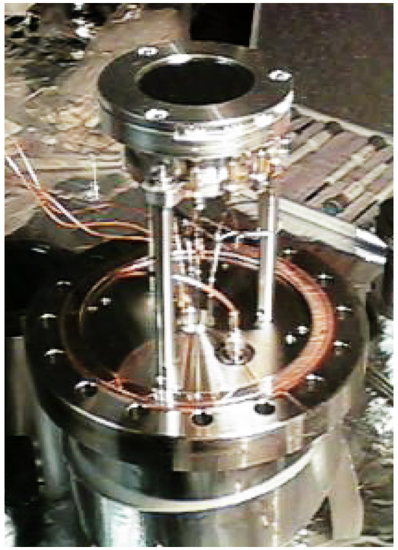
$$w_{fi} = \frac{2\pi}{\hbar} |\langle \Psi_f^N | H_{int} | \Psi_i^N \rangle|^2 \delta(E_f^N - E_i^N - h\nu)$$

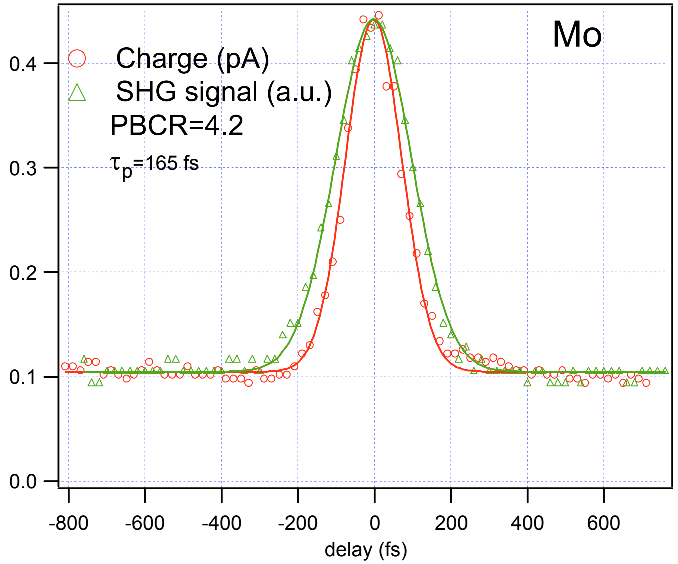
$$H_{int} = -\frac{e}{2mc}(\mathbf{A}\cdot\mathbf{p} + \mathbf{p}\cdot\mathbf{A}) = -\frac{e}{mc}\mathbf{A}\cdot\mathbf{p}$$



150 fs Laser Pulse Measured by an Electron Time of Flight Spectrometer



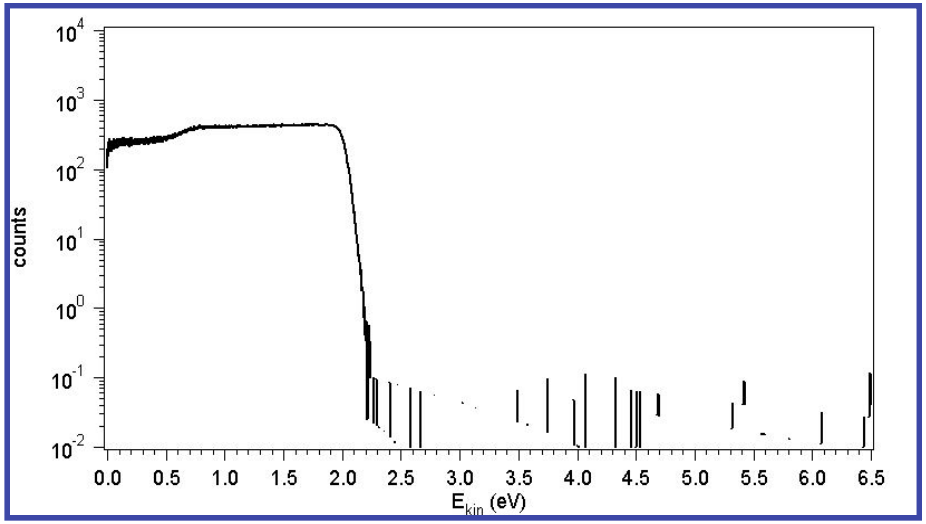


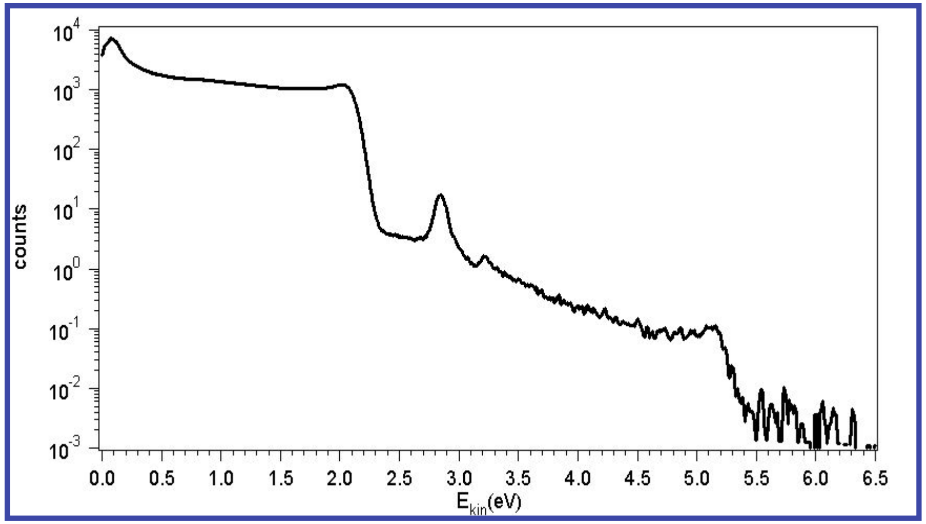


F.Parmigiani et al.

Undirectly Populated IPS on Ag(100)

Photoemission Spectra on Ag(100) single crystal

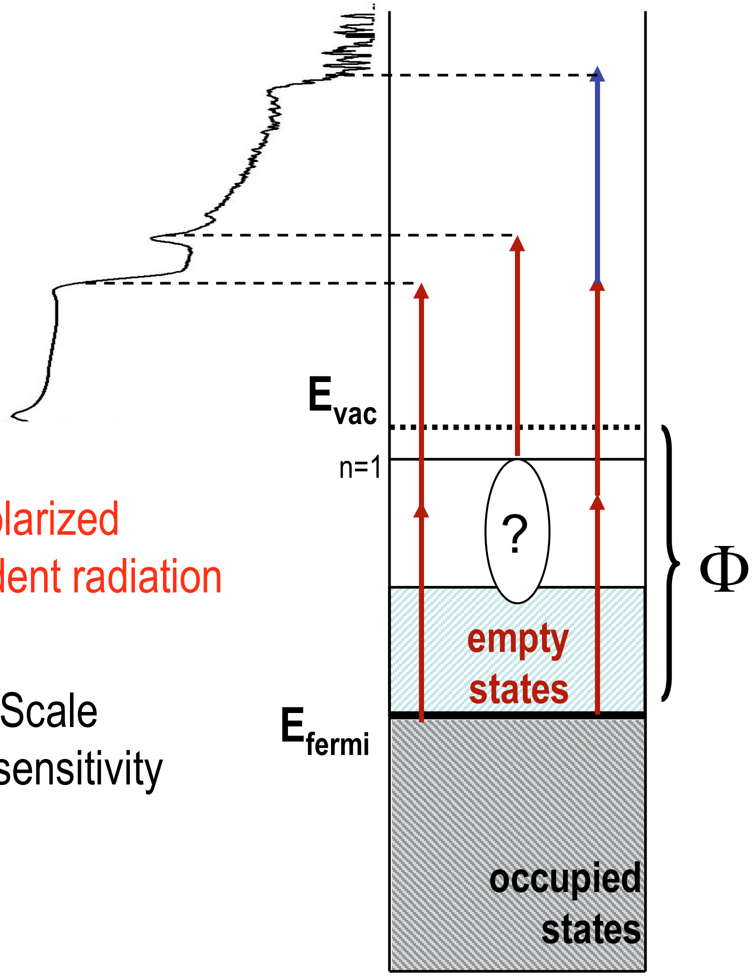




p-polarized incident radiation

Log Scale
10^6 sensitivity

I_{abs}=13 µJ/cm^2



PHOTOEMISSION PROCESS

PROBLEMS:

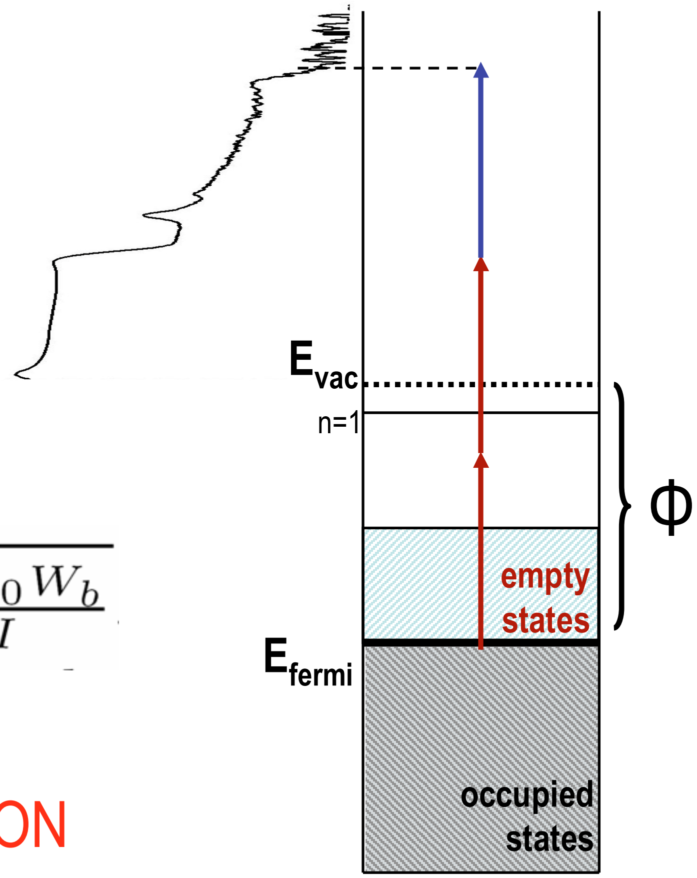
Upon the absorption of two photon the electron is already free.

Which is the absorption mechanism responsible of the free-free transition?

Keldysh parameter γ=1500>>1 perturbative regime

$$\gamma = \frac{\omega}{e}\sqrt{\frac{mc\epsilon_0 W_b}{I}}$$

Evidence of ABOVE THRESHOLD PHOTOEMISSION in solids ?



Some preliminary considerations:

- Type of experiments

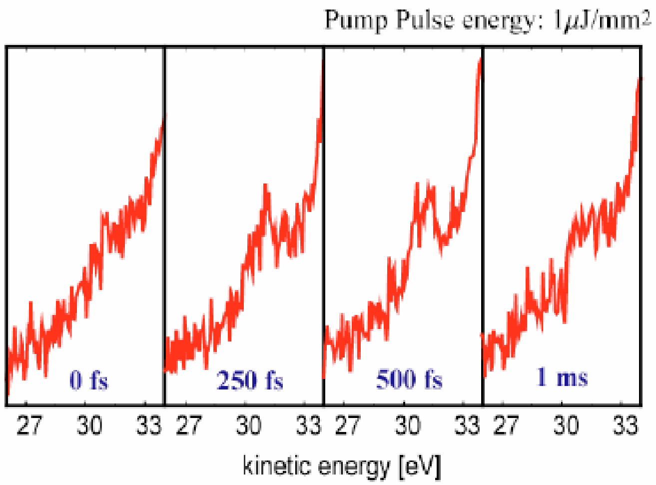
Pump-probe

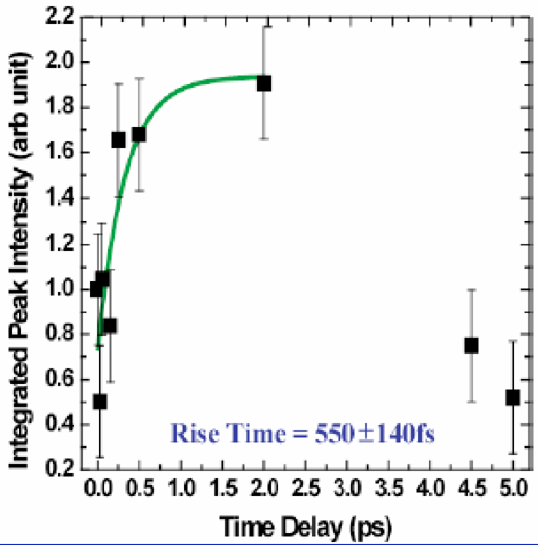
Single pulse

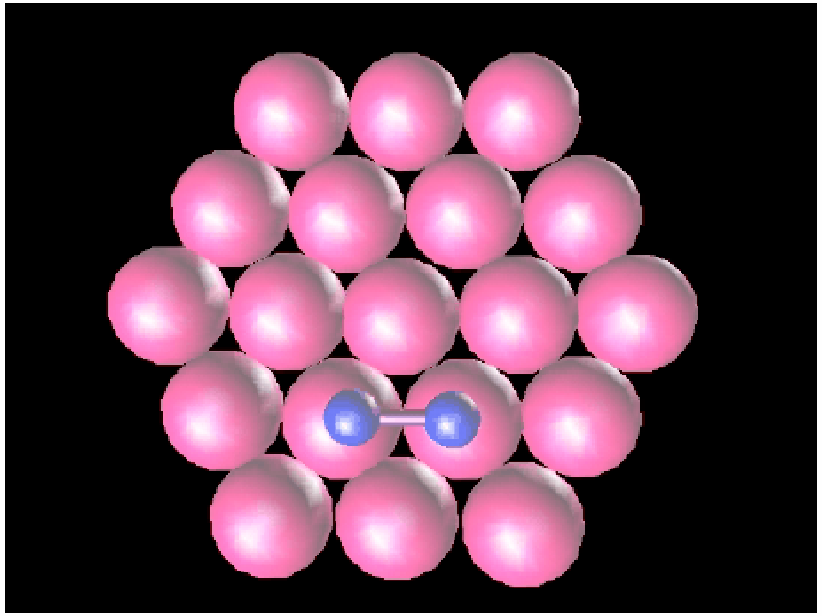
- Energy resolution / momentum resolution:

$\Delta E \times \Delta t \geq h/4\pi$

$\Delta \underline{\mathbf{p}} \times \Delta \underline{\mathbf{x}} \geq h/4\pi$







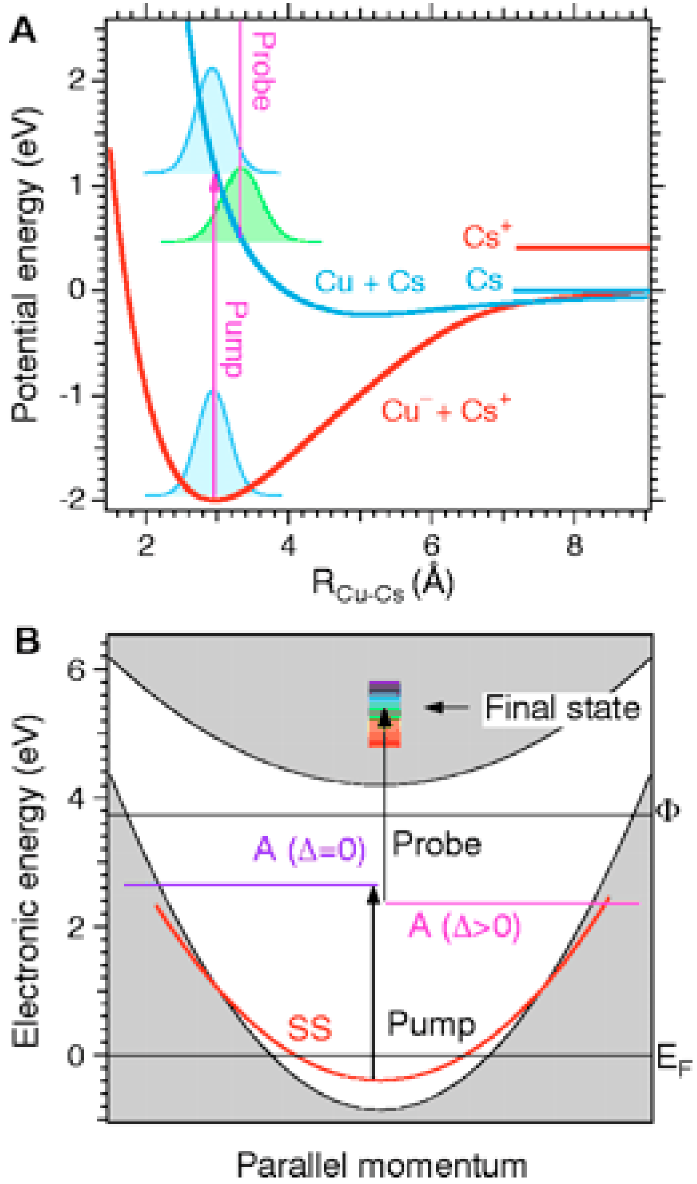
PRL 87, 25501 (2001)

Hot electron mediated surface charge transfer process on 100-500fs timescales

Real-Time Observation of Adsorbate Atom Motion Above a Metal Surface

Observation of atomic and dynamics on surface is possible by time-resolved two photon photoelectron spectroscopy. The unusual changes in the surface electronic structure within 160 fs after excitation are attributed to atomic motion in a Cu-Cs bond-breaking process.

The availability of sub ps coherent VUV and soft X-ray pulses with variable polarization will extend this technique to e very large set of systems where also the momentum and the structural parameters depending on the polarization can be explored.



H. Petek et al., Science 288 1402 (2000)