

Ultrafast Soft-X-ray Absorption Spectroscopy

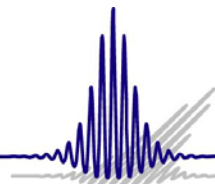
E. Seres*# & Ch. Spielmann*

**Department of Physics EP1
University of Würzburg*

*# Photonics Institute, Vienna University of
Technology*

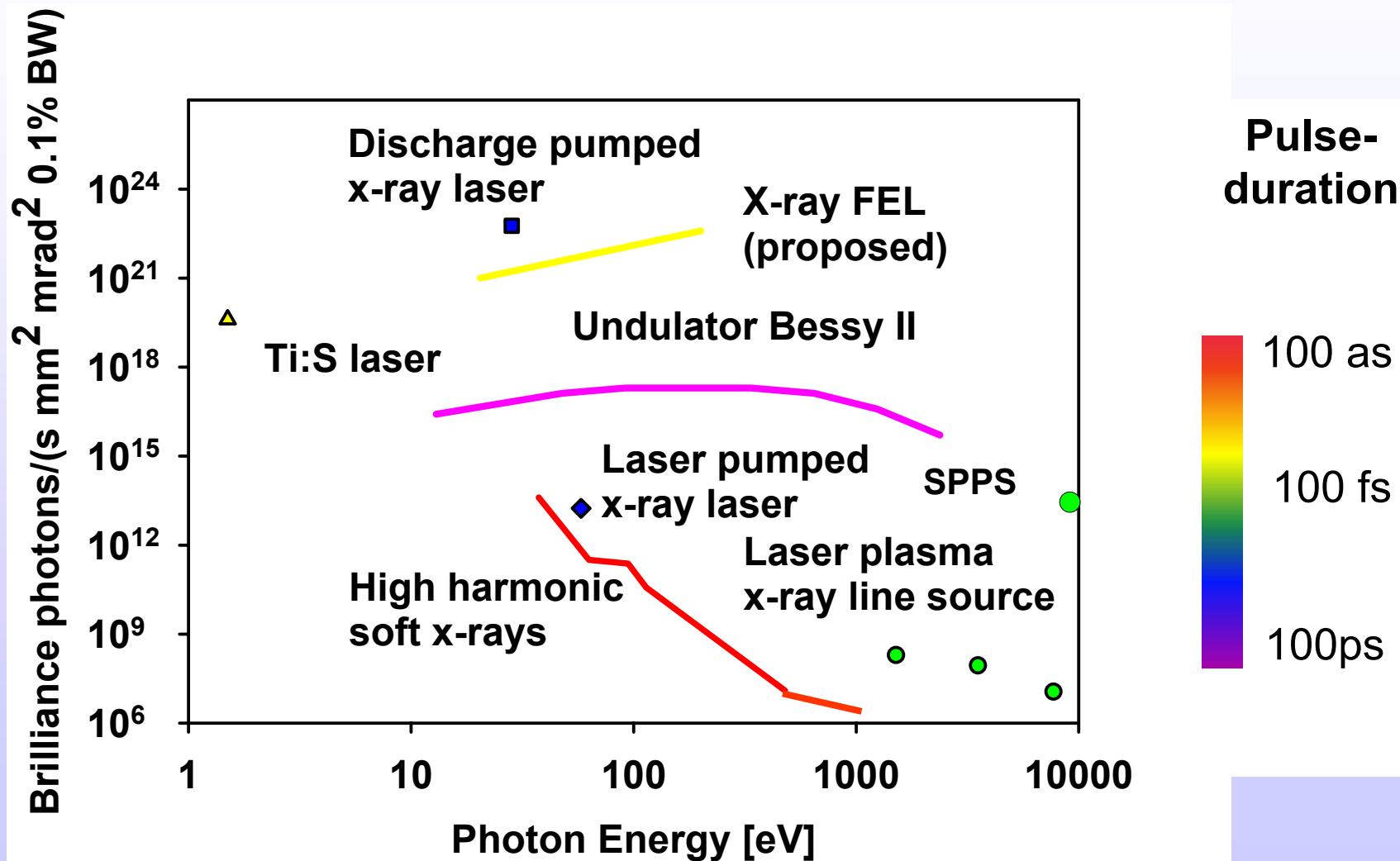


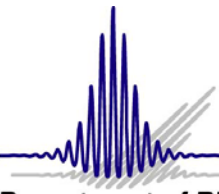
Financial support DFG (SP 687/1-2) and
Austrian Science Fund (F016 P03)



Pulsed X-ray sources

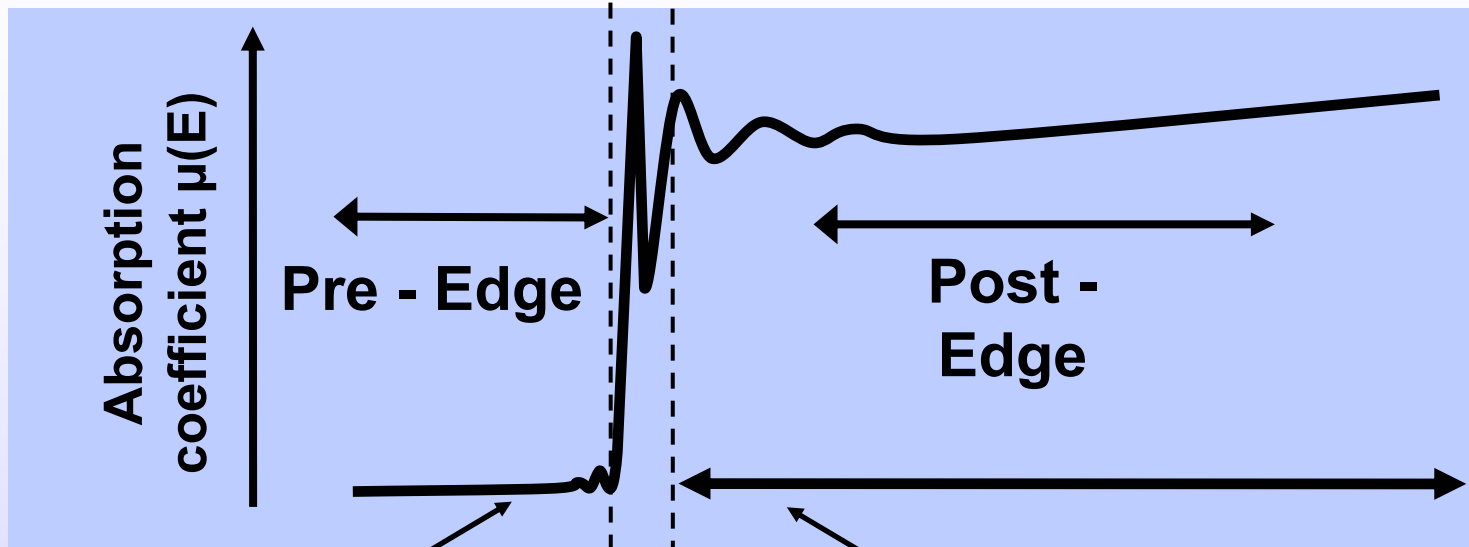
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X-ray absorption spectroscopy

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XAMES
X-RAY ABSORPTION MAIN EDGE
STRUCTURE

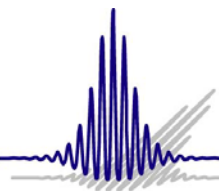
- coordination number
- coordination geometry

EXAFS (> 50eV)
X-RAY ABSORPTION EXTENDED FINE
STRUCTURE

- atomic distances
- neighboring atomic species

XANES (< 10 eV)
X-RAY NEAR ABSORPTION EDGE SPECTROSCOPY

- band structure
- Molecular orbitals

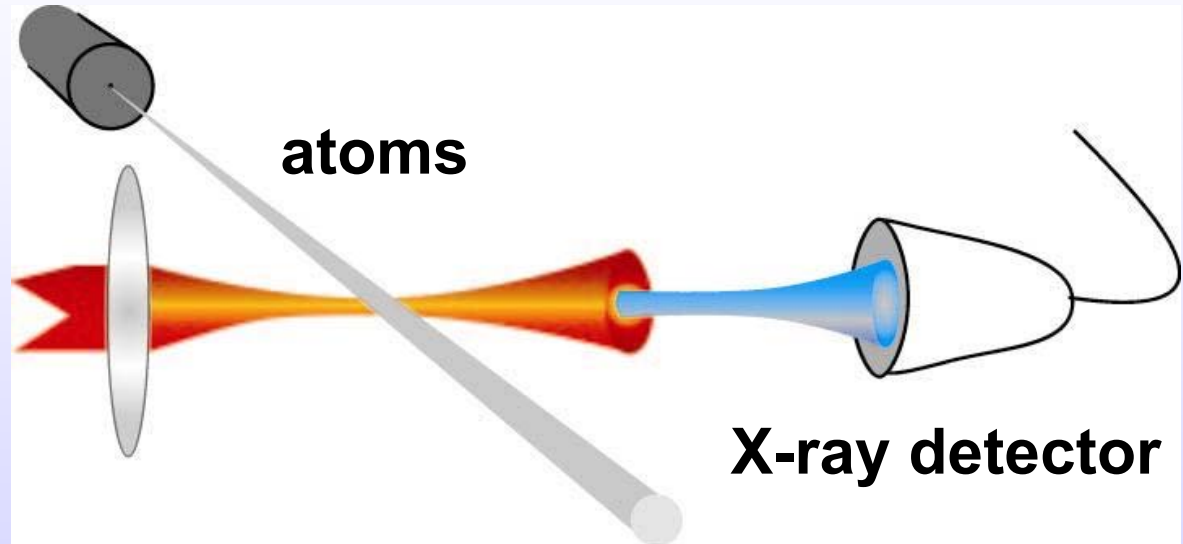


High Harmonic Generation (HHG)

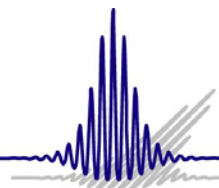
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Femtosecond laser
pulse ($> 10^{14} \text{ W/cm}^2$)

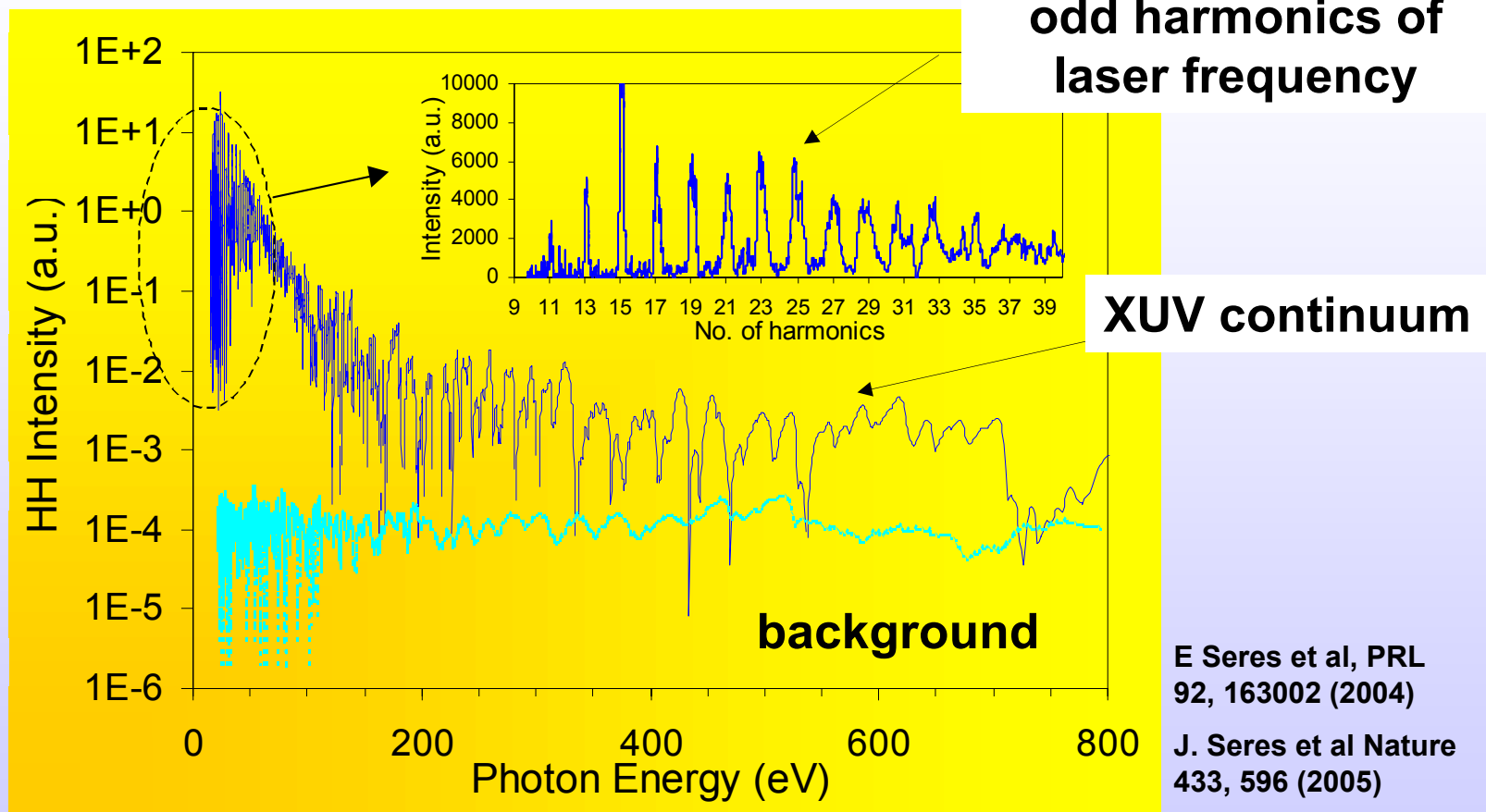


Laser radiation is up-converted into spatially
coherent soft x-ray radiation



HHG Spectrum

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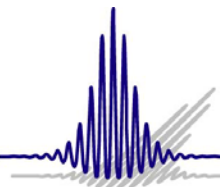


E Seres et al, PRL
92, 163002 (2004)

J. Seres et al Nature
433, 596 (2005)

Laser pulses with ~ 12 fs $> 10^{16}$ W/cm² $\lambda = 780$ nm focused into Neon

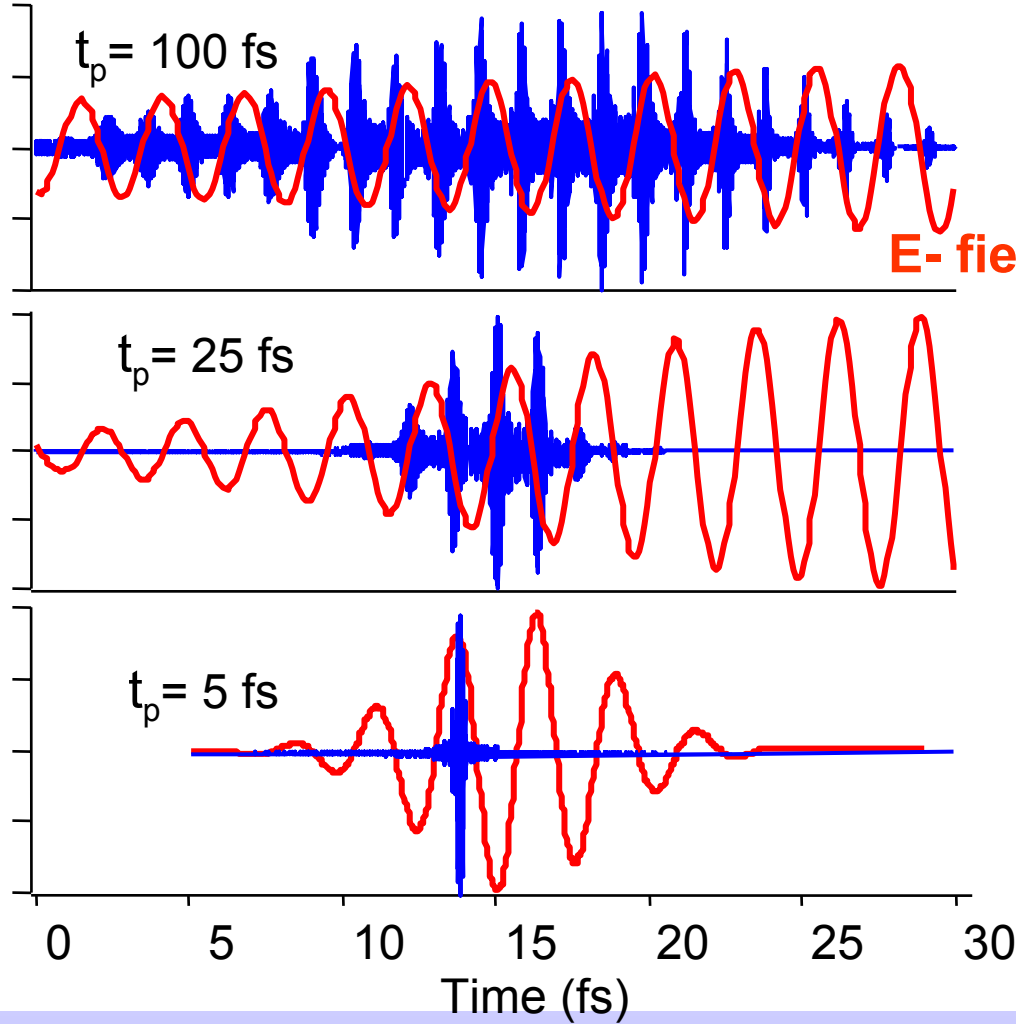
| | | |
|---------------------|---------------------|----------------|
| Photons/s (10% BW): | C K-edge (284eV): | $2 \cdot 10^7$ |
| | Ti-L-edge (453 eV): | $1 \cdot 10^6$ |



HHG: Temporal Characteristic

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XUV radiation



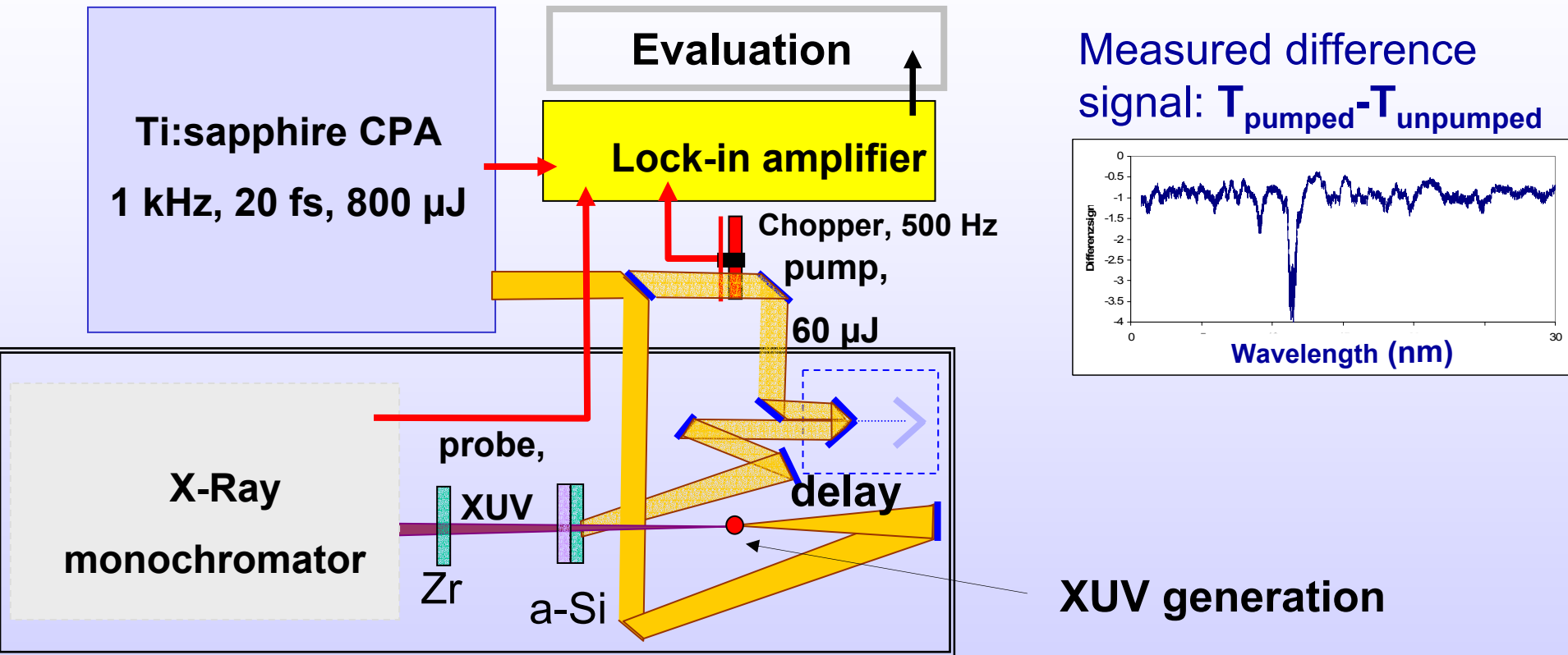
**HH coherent process:
XUV emission only within
laser pulse duration**

**After spectral filtering:
train of sub-fs pulses**

**single attosecond pulse
possible**

Time-resolved XAS

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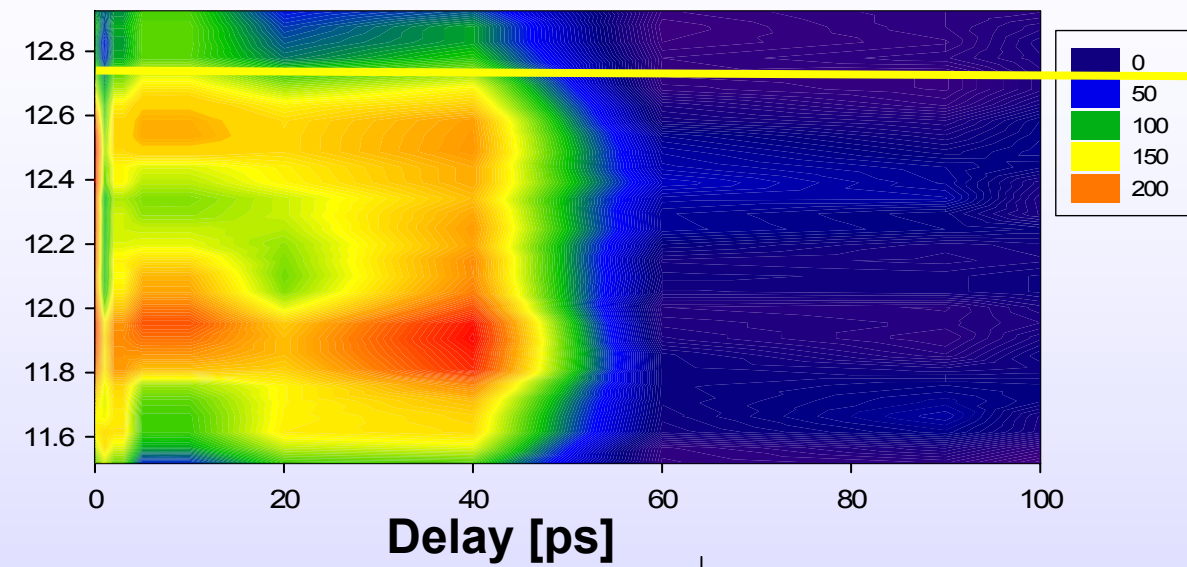
Sample: polycrystalline (amorphous) Silicon (100nm thick)

Pump: 780nm, 20fs 2-5 mJ/cm² ($10^{19}\text{cm}^{-3} < N_0 < 10^{20}\text{cm}^{-3}$)

**Probe: XUV continuum 100-600eV, < 20fs,
spot size on sample 1mm x 1mm**

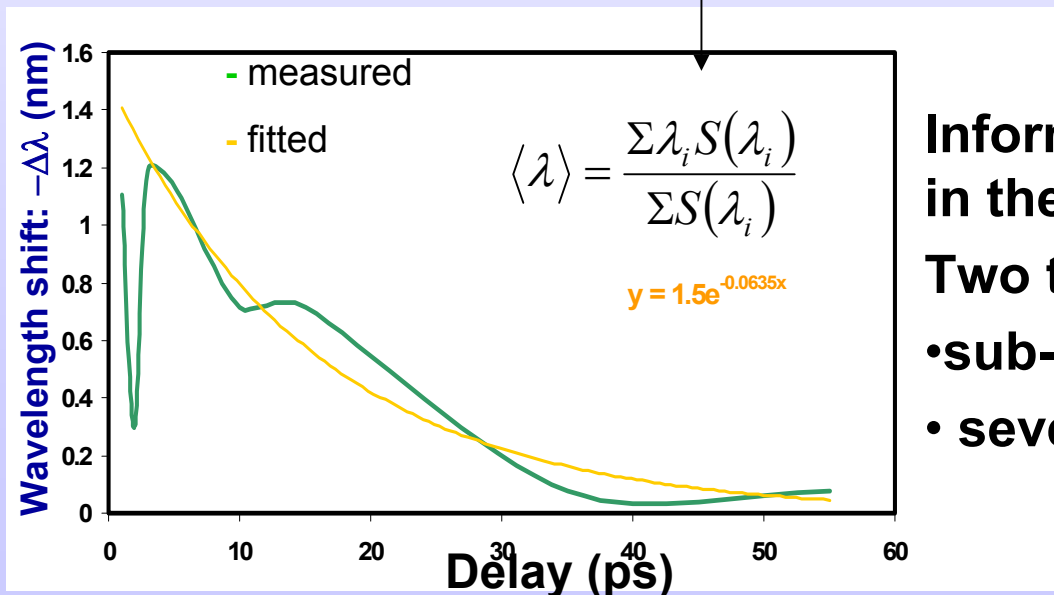
XAMES @ Si L-edge

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Si L_{II,III} absorption edge

Measured differential transmission spectra



Information about carrier distribution in the valence and conduction band

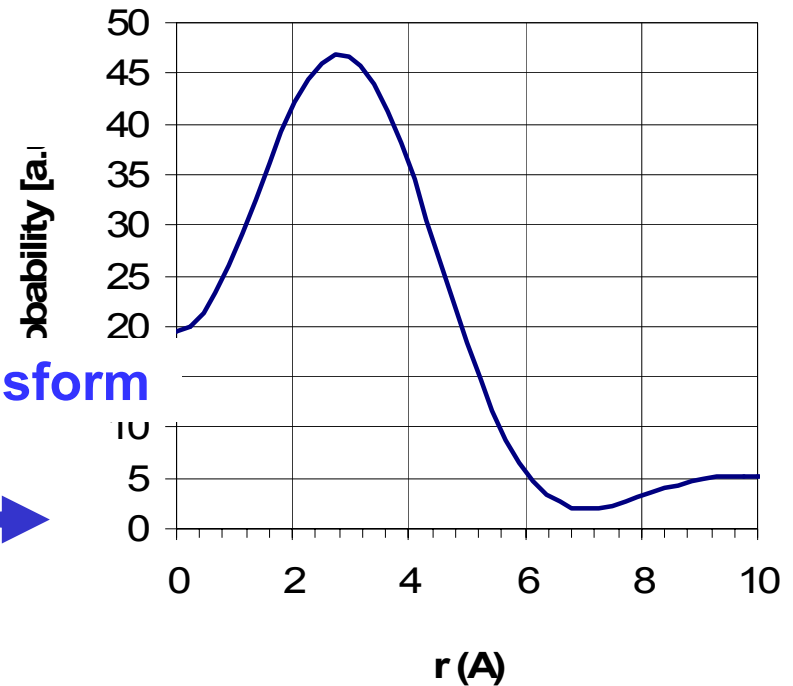
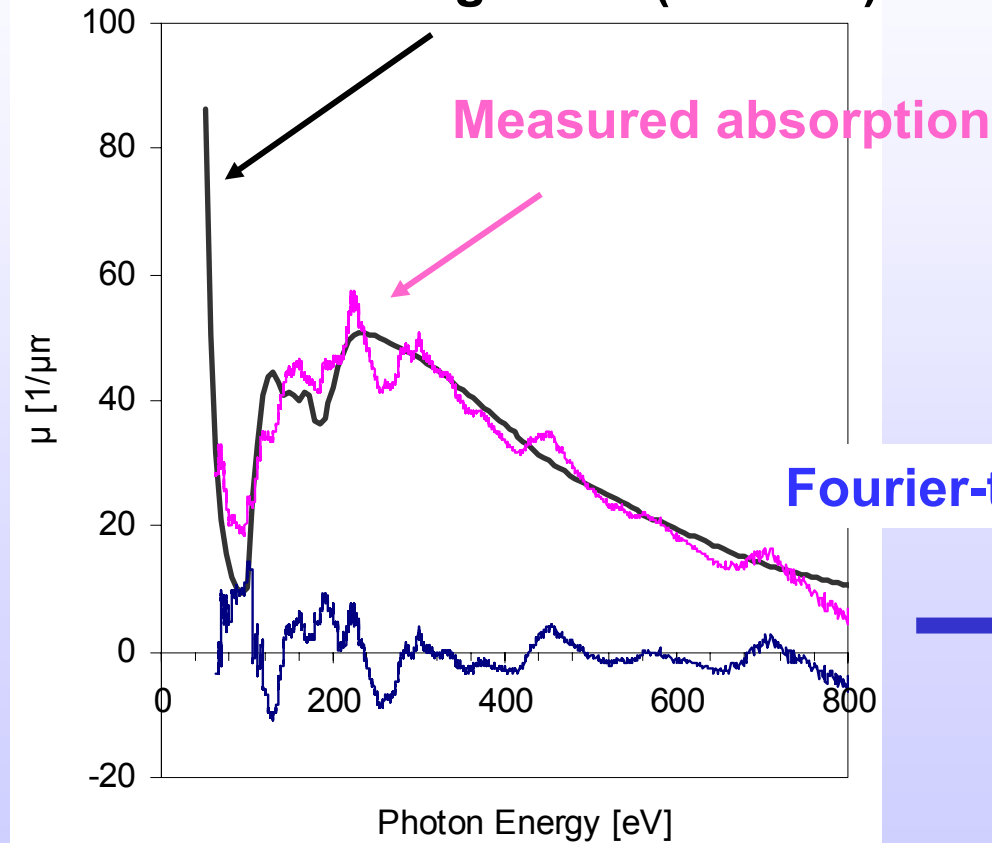
Two time constants observed:

- sub-ps: electron-phonon scattering
- several 10's of ps: recombination

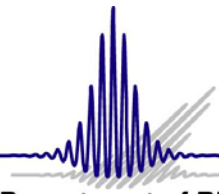
EXAFS Si L-edge

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Background (Si atom)



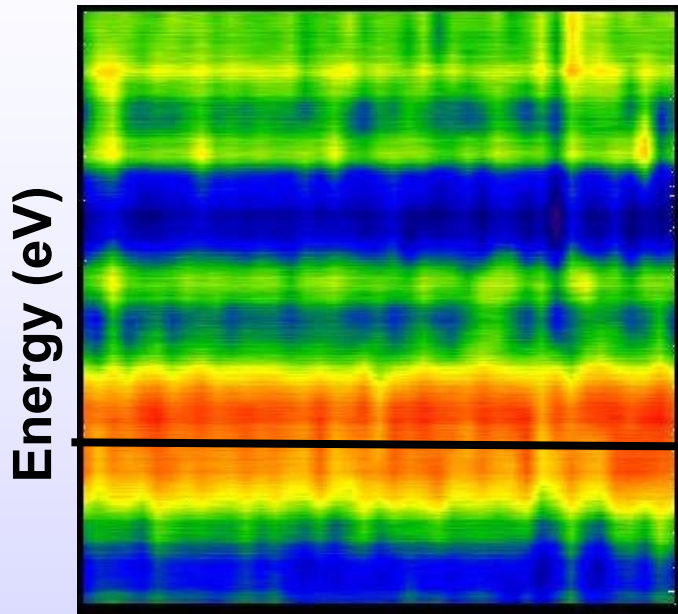
Calculated separation $r = 2.46\text{Å} \pm 10\%$
(Literature: amorphous Silicon: 2.37 Å)



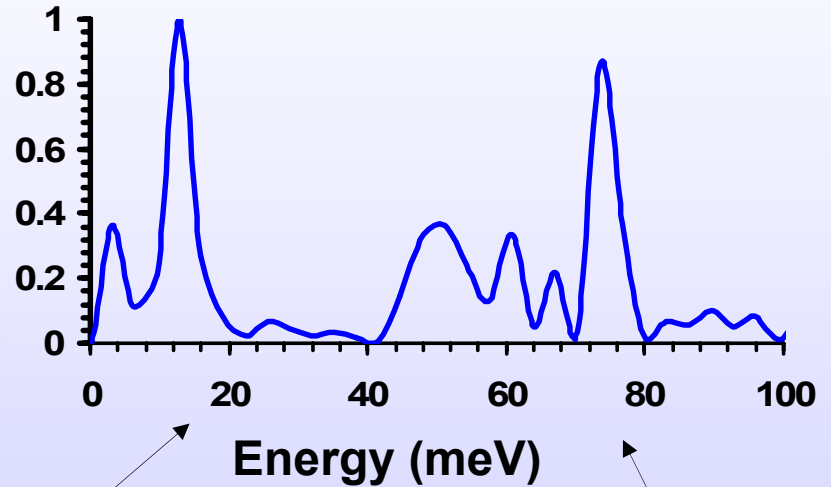
T-EXAFS

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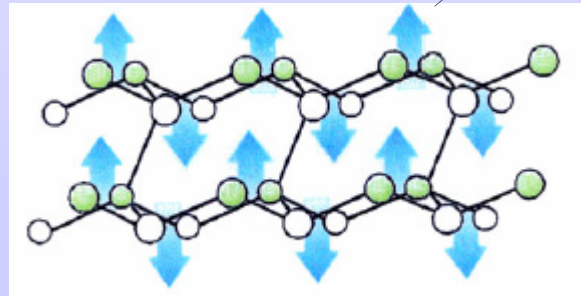
Energy 100 ..500eV
Delay 0..800fs, 20fs steps



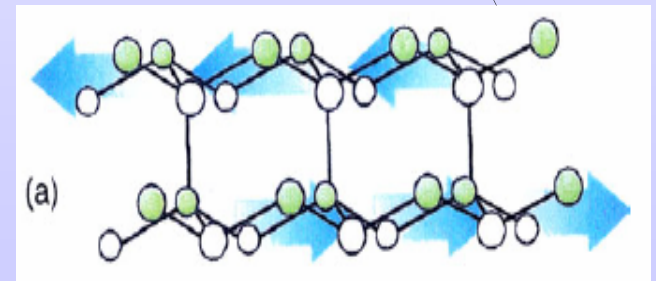
Fourier-
transform



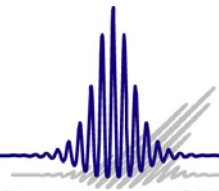
Delay (fs)



TA – phonon



LO -phonon



Conclusion Outlook

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- **High harmonic radiation has been used for soft x-ray absorption spectroscopy with sub-20fs resolution**
- **Measured carrier dynamics with T-XAMES**
- **Measured lattice dynamics (coherent phonons) with T-EXAFS**
- **Improving the setup**
- **Time-resolved studies in the water window**