"…the attoworld is as far from our experience as the age and size of the universe…"

Attoseond processes in atoms

Rydberg states n > 1 fs ... µs

Heisenberg:
time ↔ energy : $\Delta t \sim h/\Delta E$

Valence n = 1 ~ 1 fs

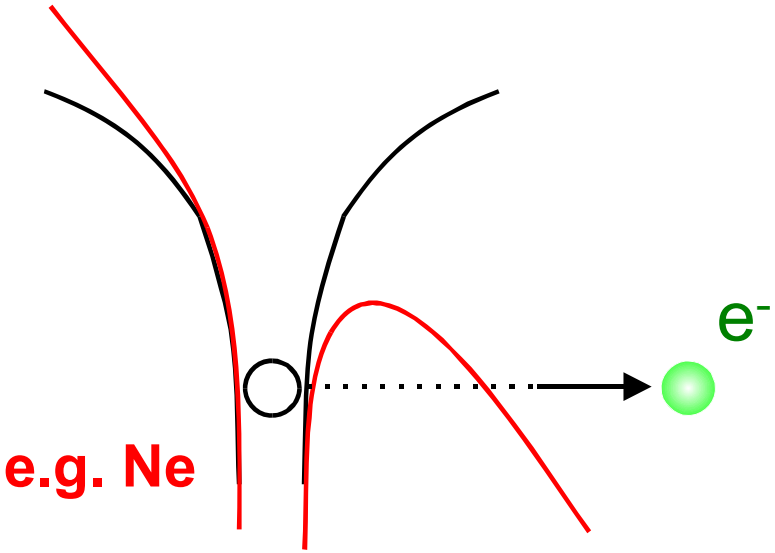
innershell < 1 fs

attosecond dynamics:
innershell processes

however visible light: T ~ 2 fs

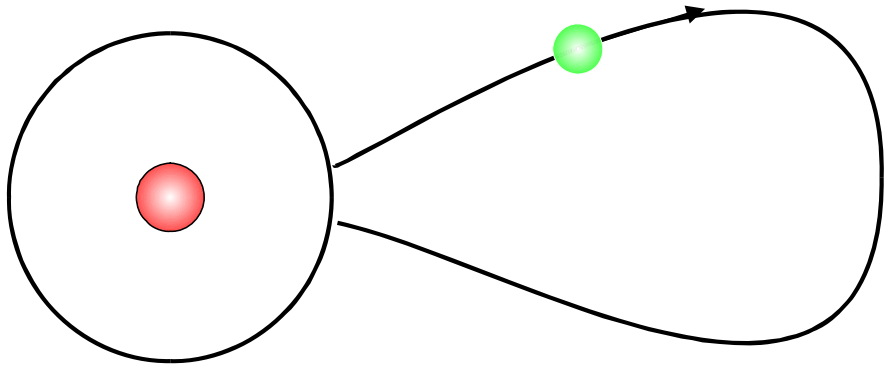
⇒ **need: attosecond x-ray pulses**

High harmonic generation (HHG)

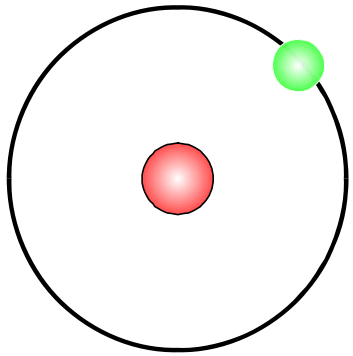


1. tunneling ionization
   for I > 10^{14} W/cm^2

2. electron accelerated
   in the laser field

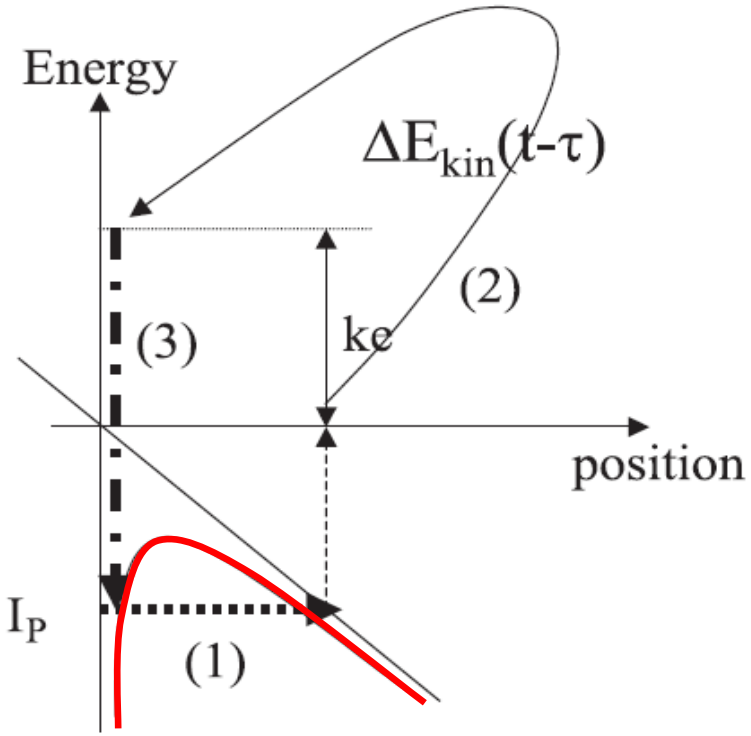


3. recombination with ion core and
   emission of high energy photon

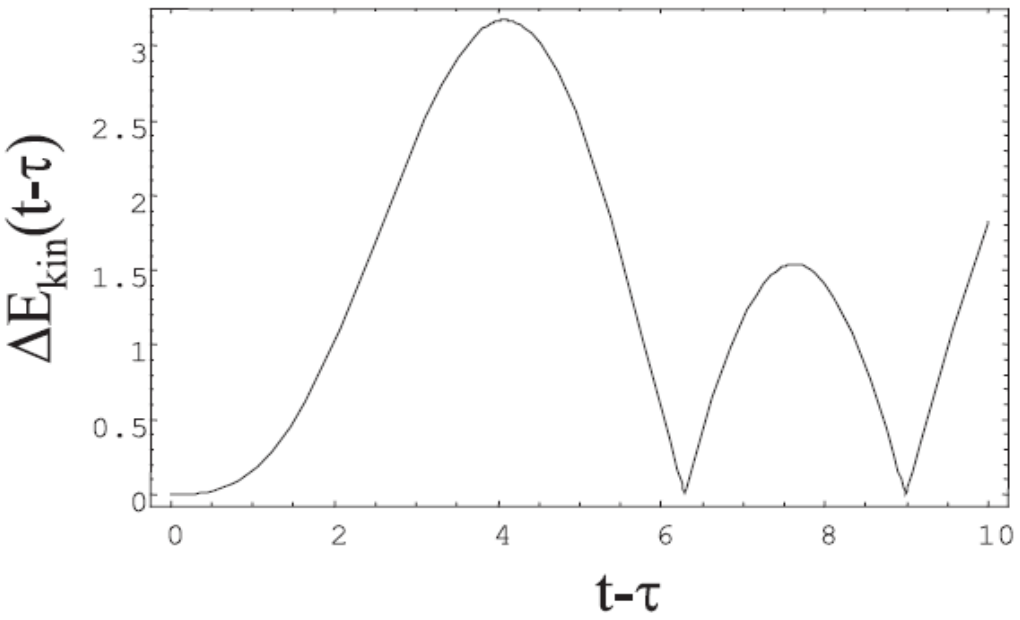


$h\nu_X = n * h\nu_{Laser}$ *(n odd)*

3 step model for HHG



Agostini, DiMauro, Rep. Prog. Phys. **67** (2004) 813

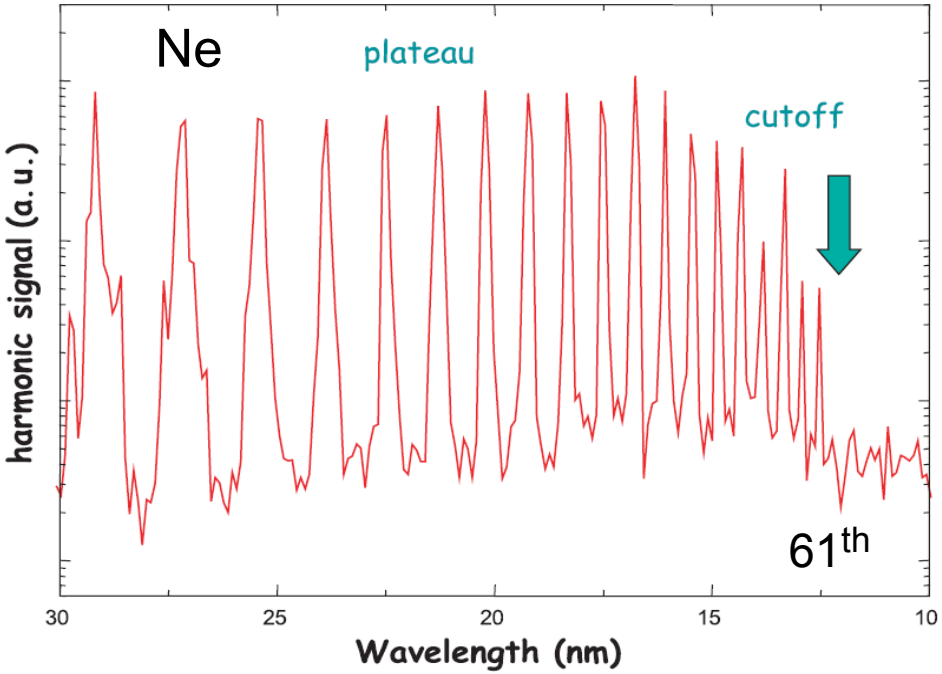


HHG cutoff determined by maximum available energy

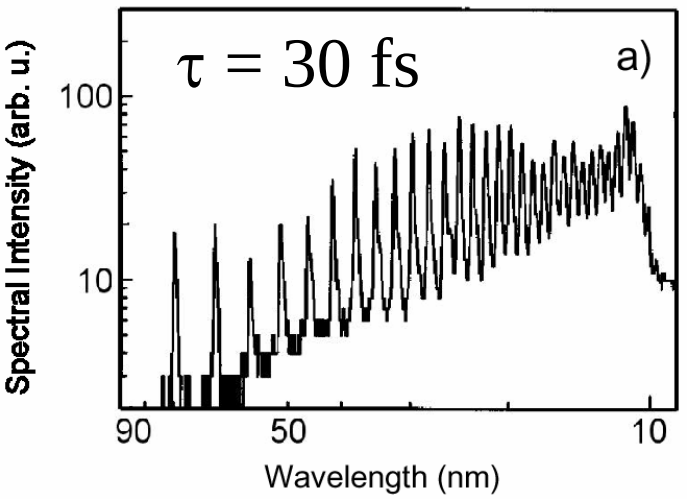
$$E_{max} = 3.2\ U_p + I_p$$

with ponderomotive potential

$$U_p = e^2E(t)^2/4m\omega_L^2$$



„long“ fs laser pulses : periodic process

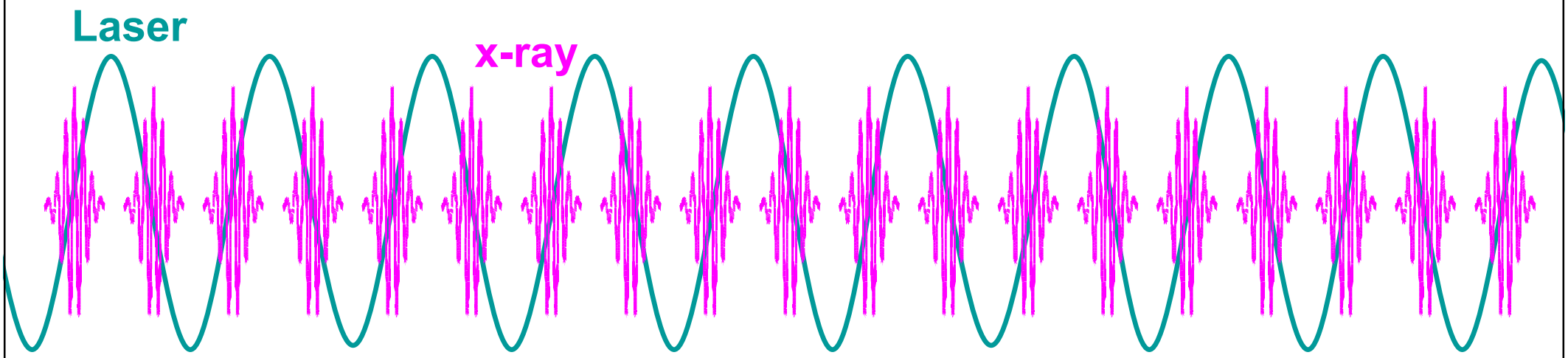


periodic spectrum

$h\nu_{XUV} = n * h\nu_{Laser}$

n 3...> 500

train of x-ray pulses



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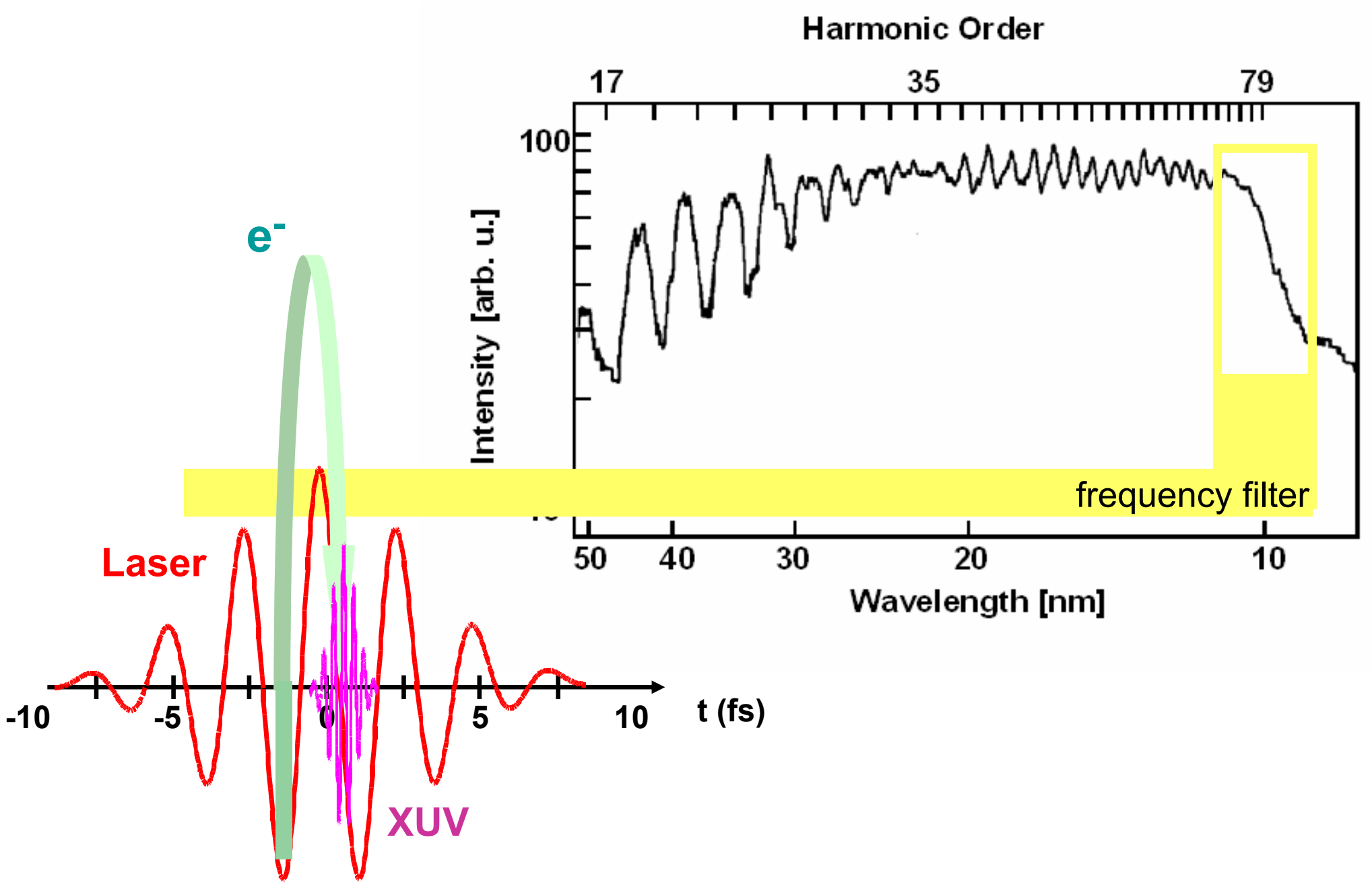
„few-cycle“ laser pulses: single attosecond flash



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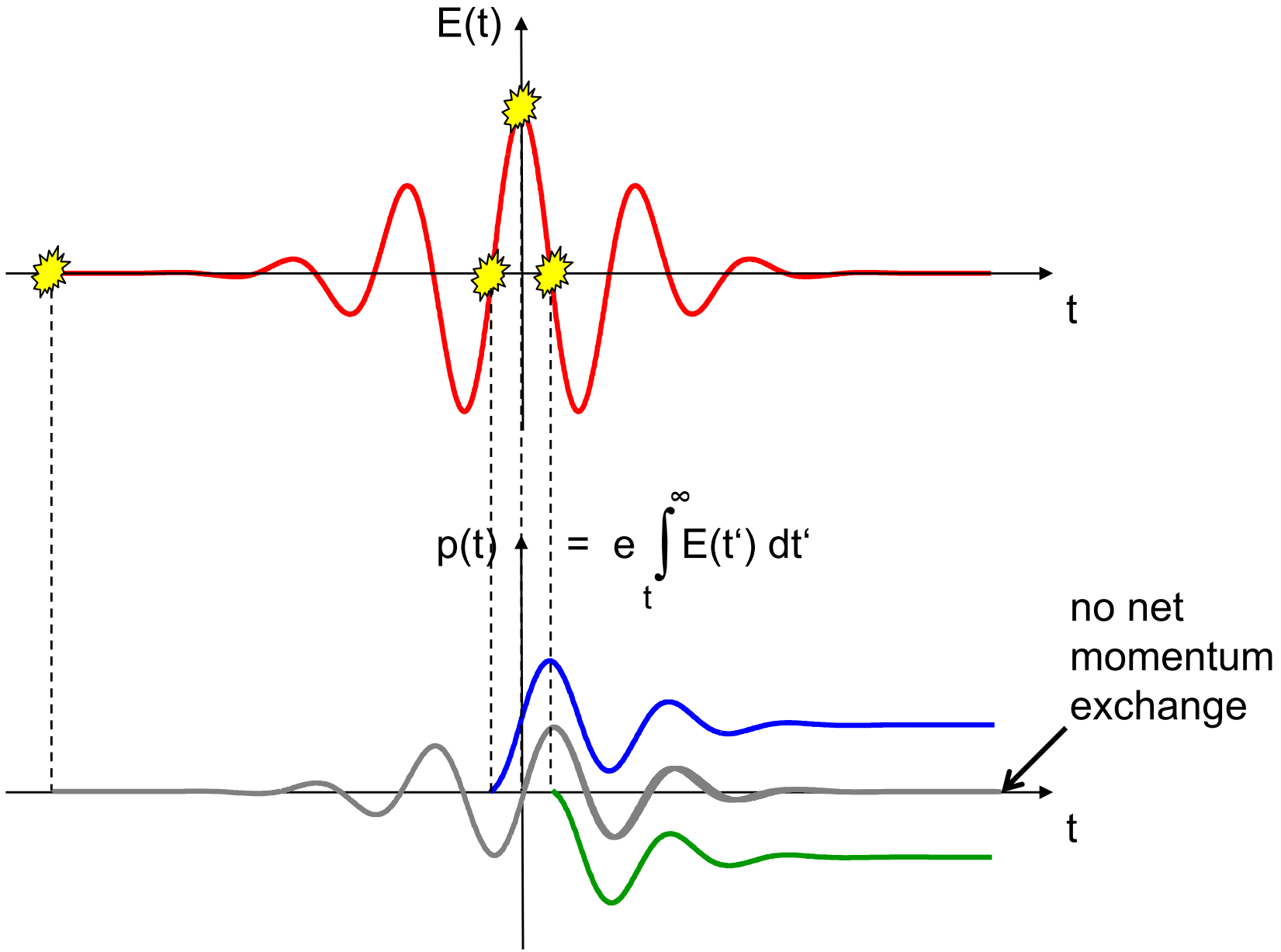
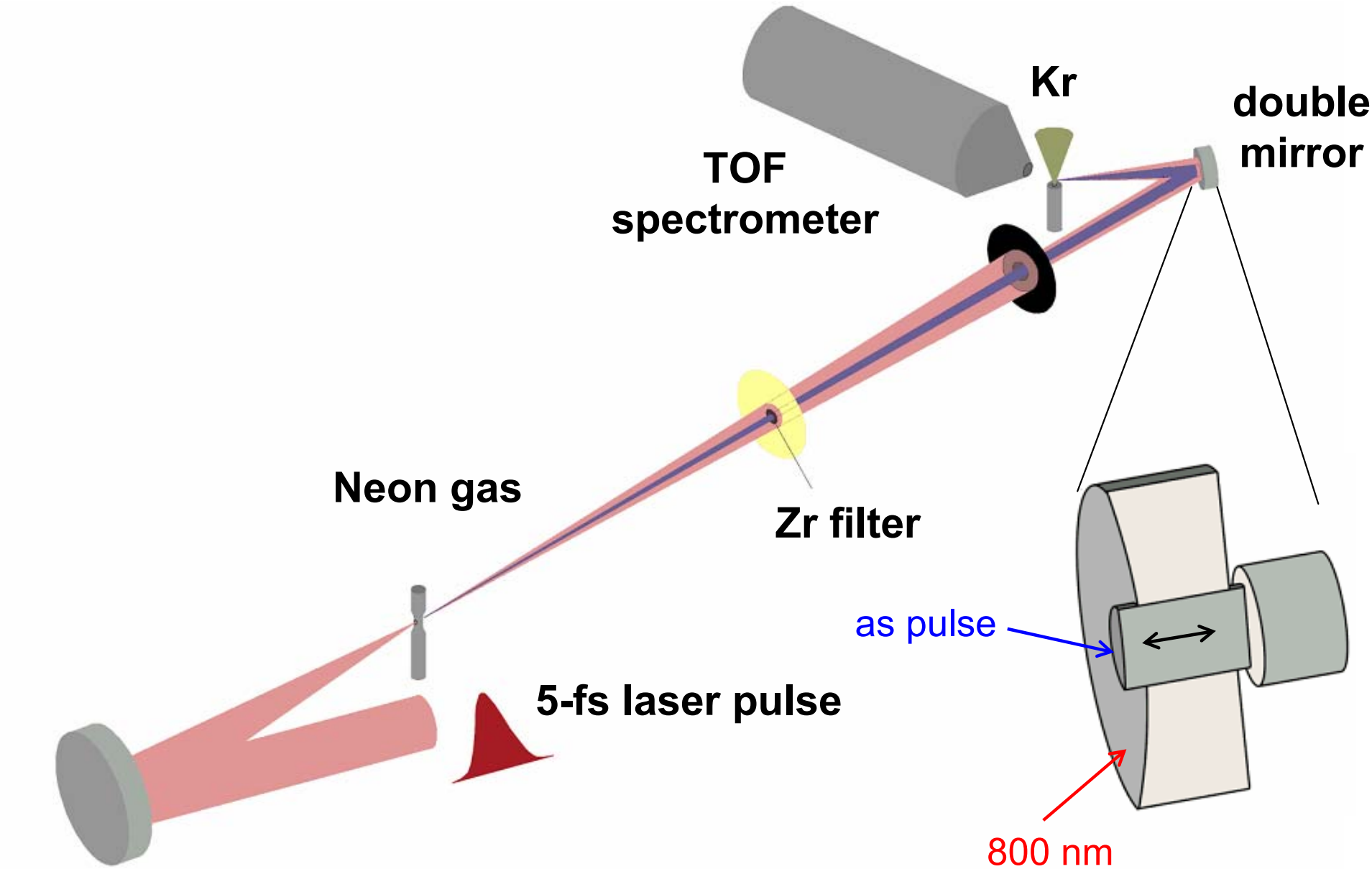
Electron injection in a laser field:

→ ***momentum*** **exchange between light and electron**

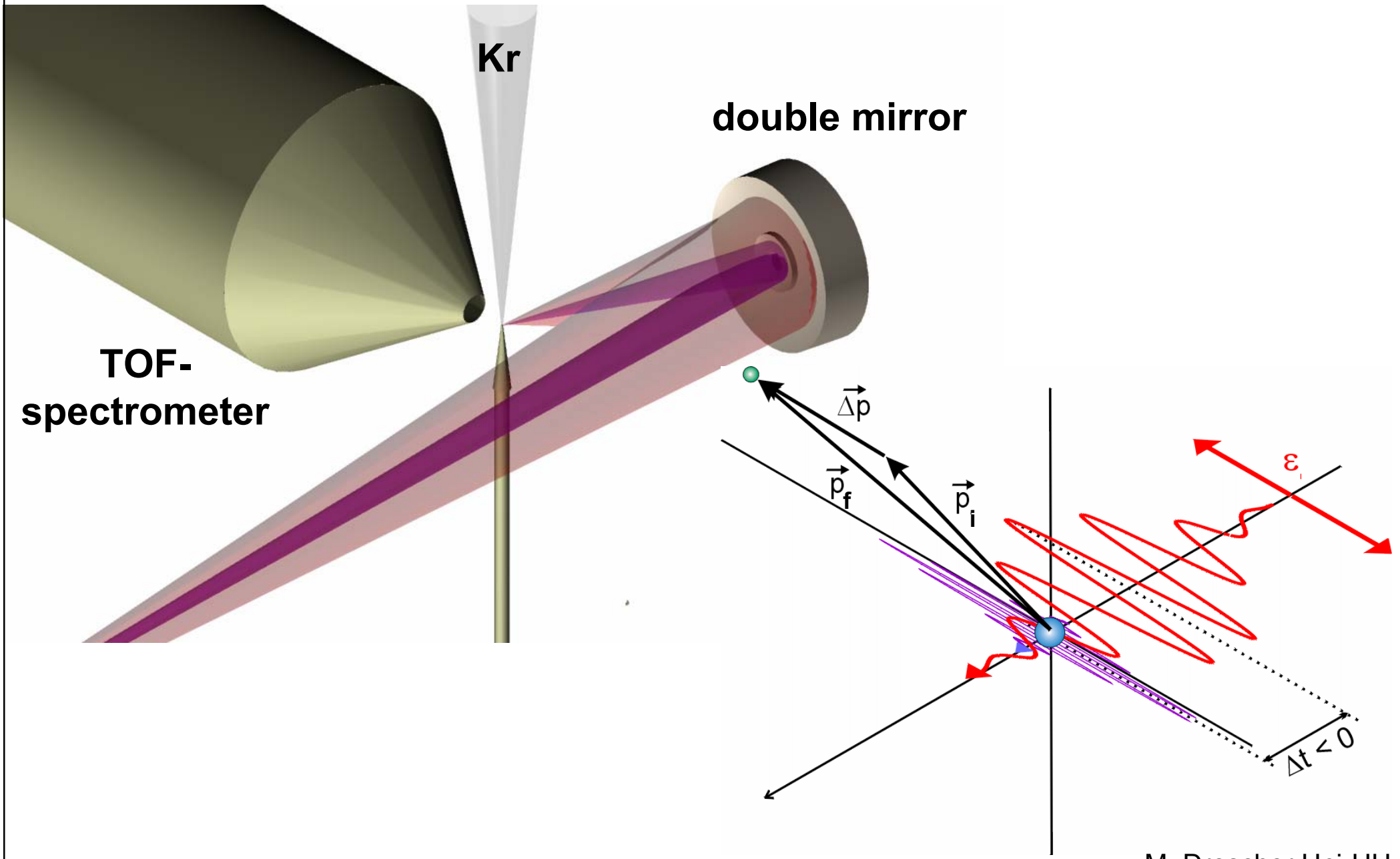


Setup for time-resolved electron spectroscopy



M. Drescher et al., Science 291, 1923 (2001)

momentum transfer → kinetic energy shift



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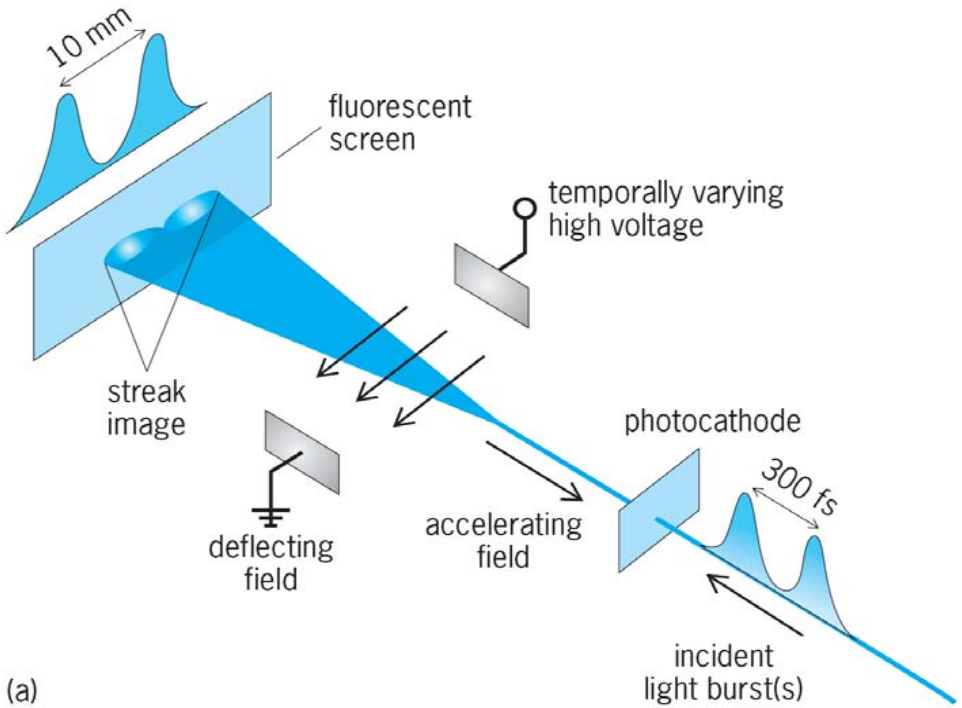
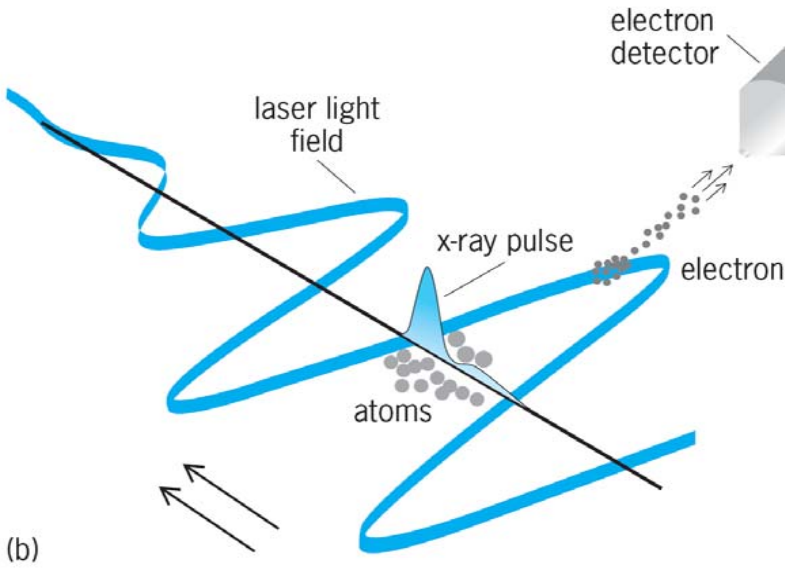
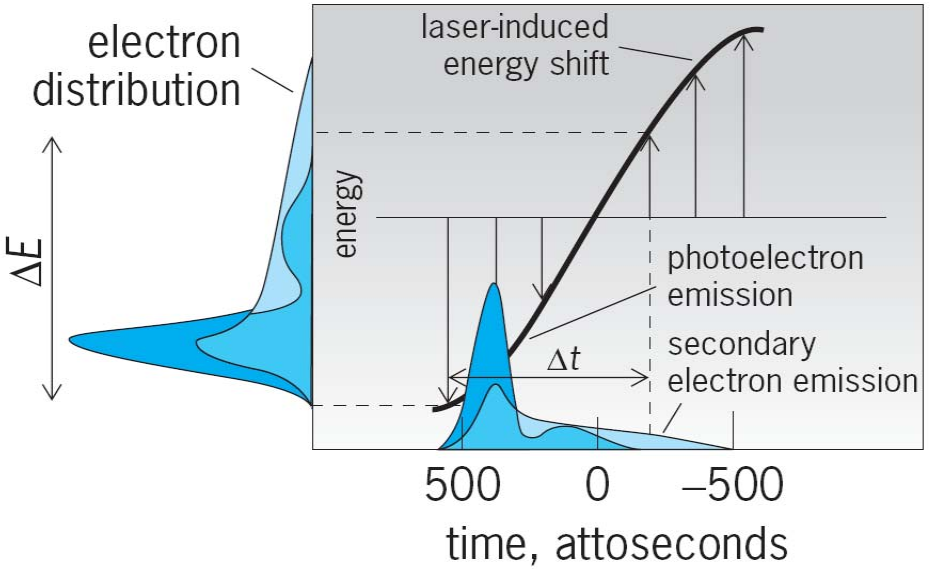
The Attosecond Streak Camera

Principle

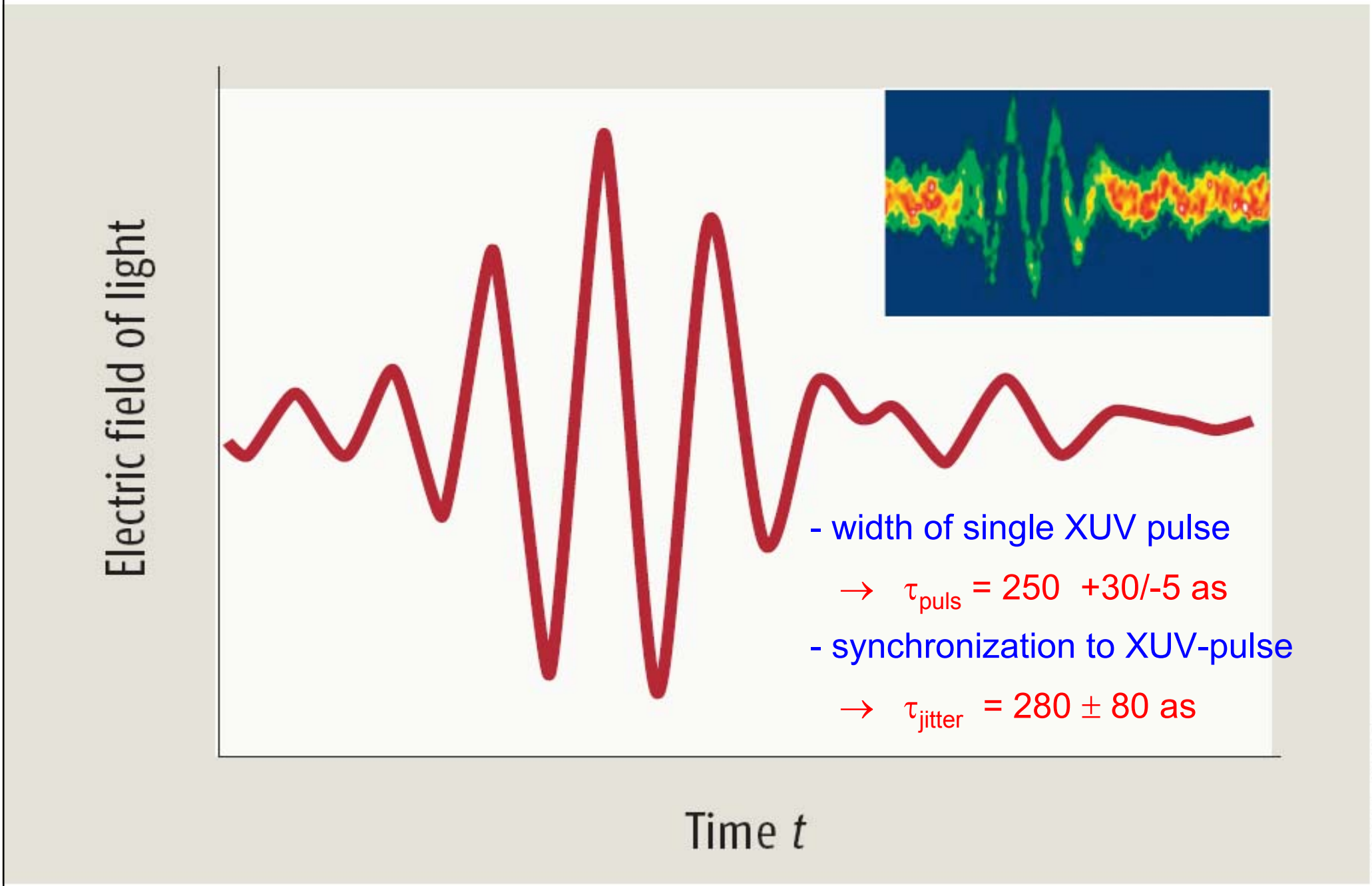


R. Kienberger, F. Krausz
McGraw-Hill Yearbook 2006



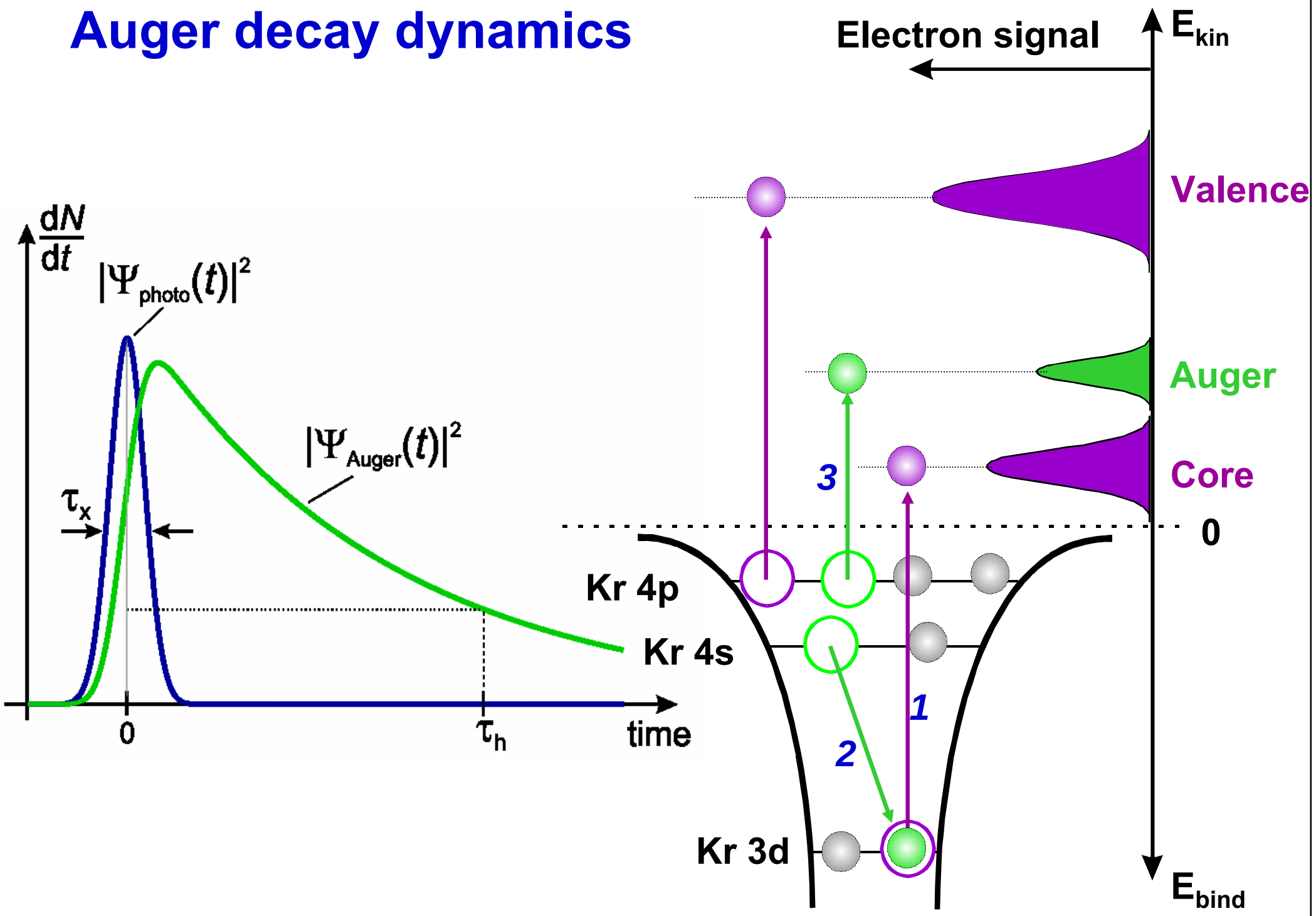


Light metrology: direct snapshot of the light field

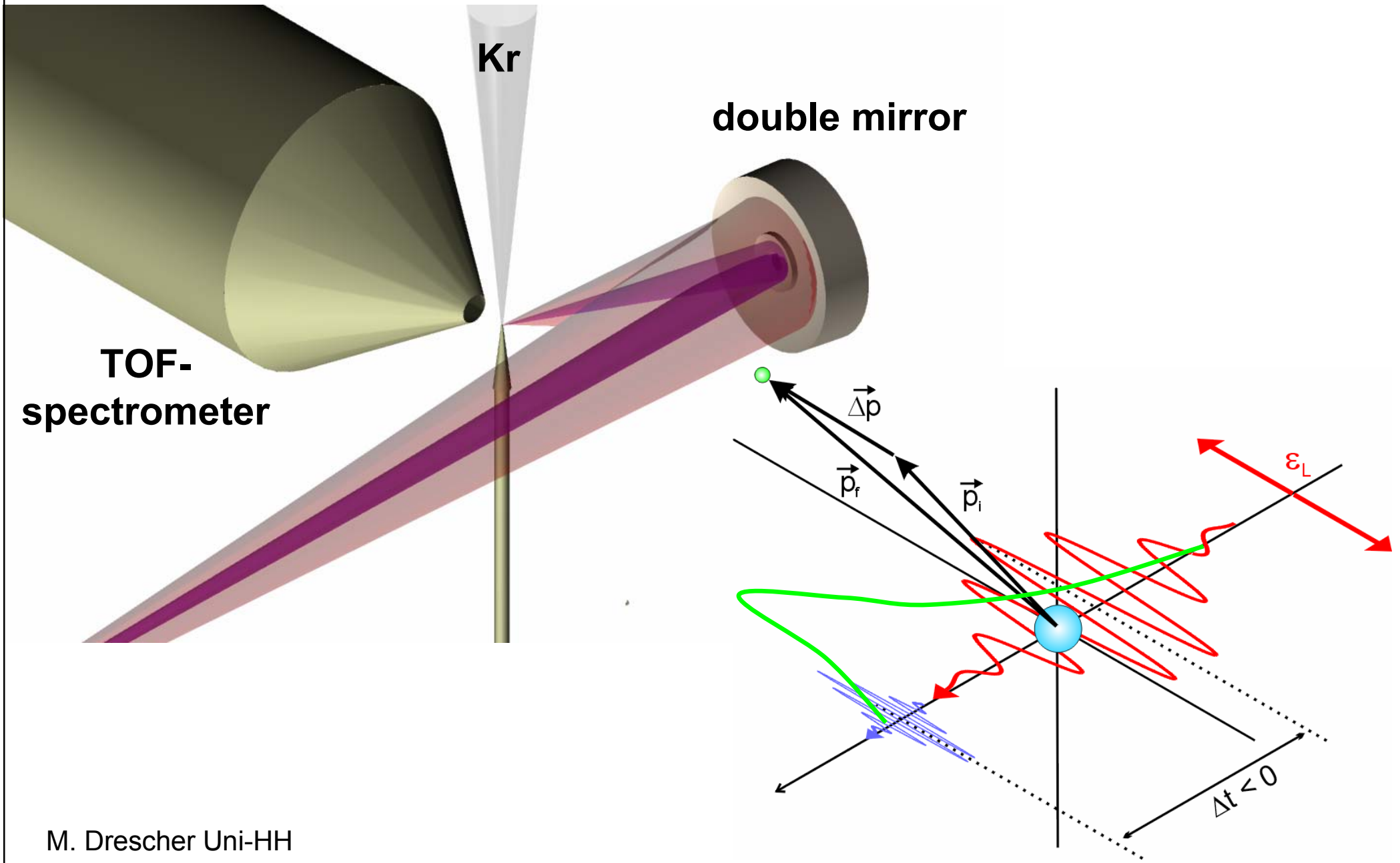


E. Goulielmakis et al., Science 305, 1267 (2004)

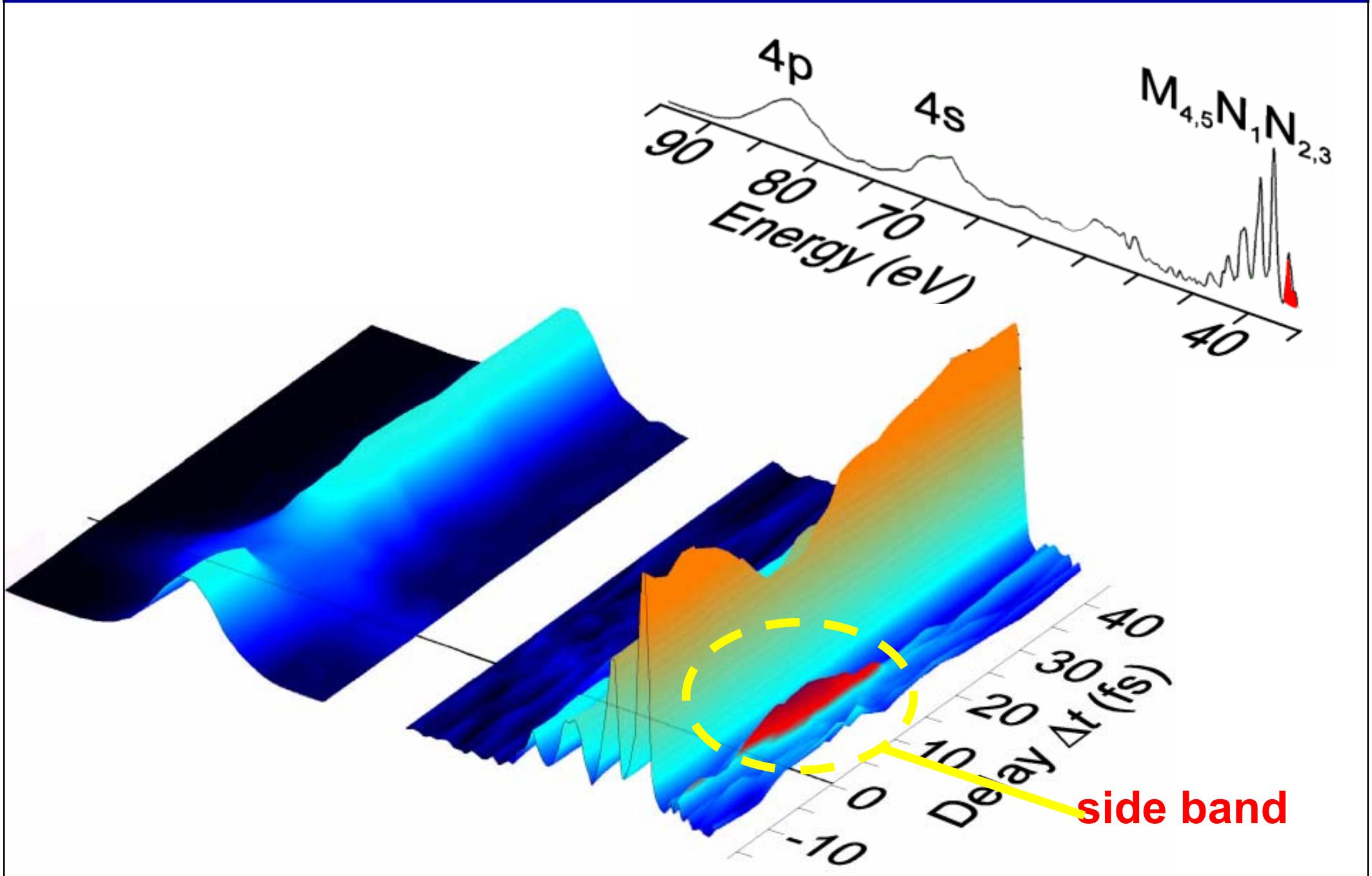
Auger decay dynamics



Probing the Auger electron wave packet

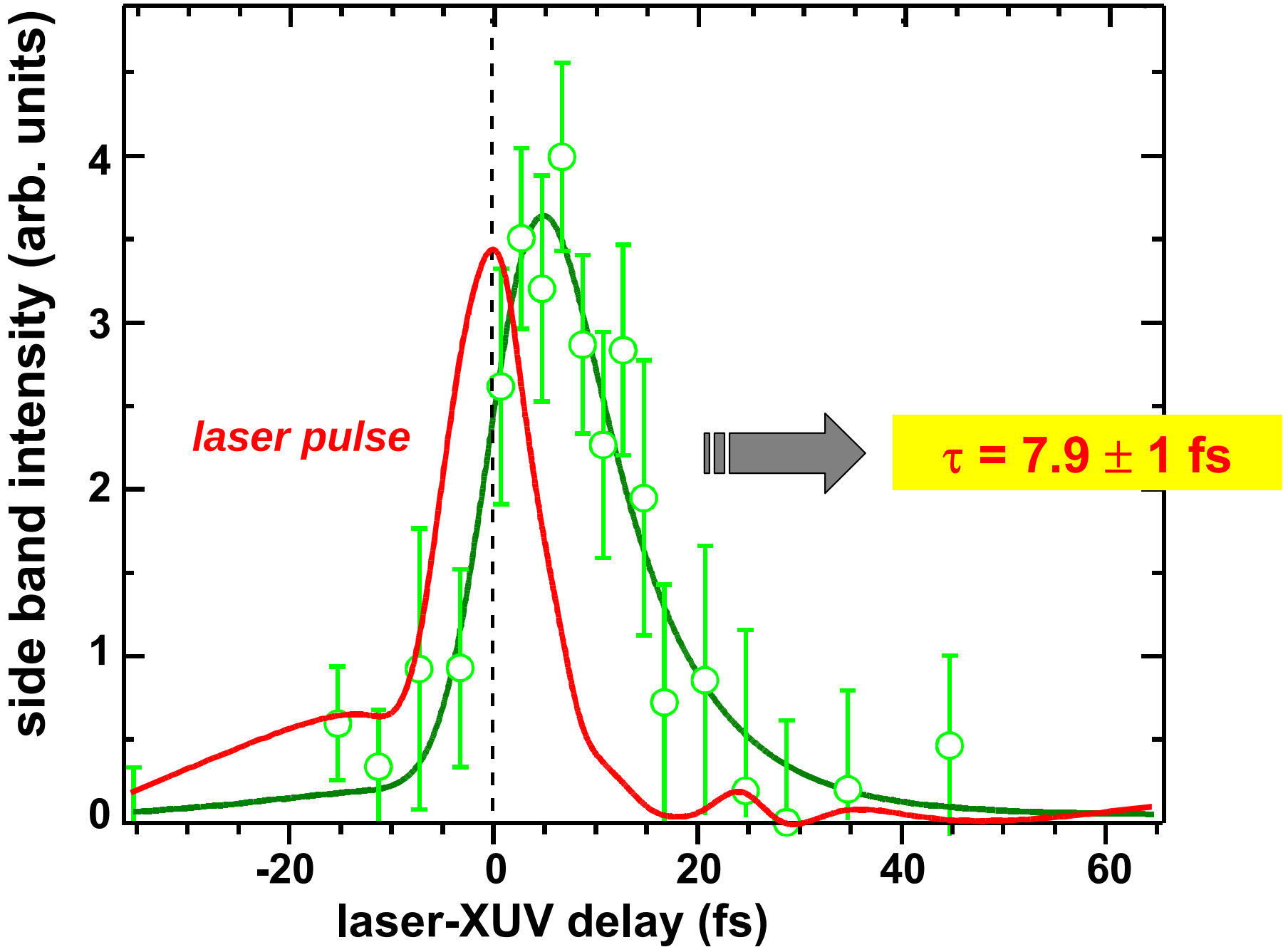


time-resolved Auger/photoelectron spectra of Kr



M. Drescher et al., Nature 419, 803 (2002)

time evolution of Kr side band



M. Drescher et al., Nature 419, 803 (2002)

summary

Introduction

→ Non-adiabatic processes at surfaces: Chemicurrents

Surface femtochemistry

→ Surface dynamics with electronic friction

→ Example: Associative desorption of H_2 from Ru(0001)

Time-resolved probe of structural dynamics

→ Femtosecond laser spectroscopy

→ Time-resolved x-ray diffraction

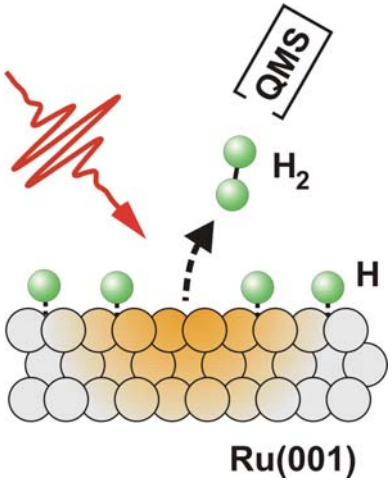
→ Non-thermal melting and coherent phonon excitation

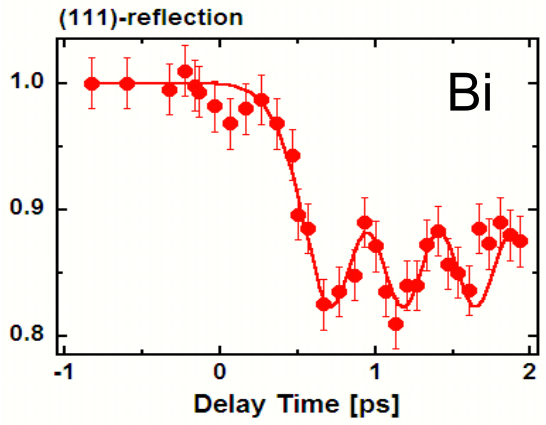
→ Time-resolved photoelectron spectroscopy

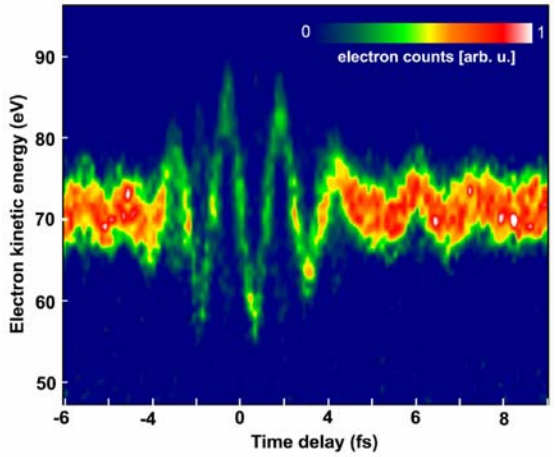
Attosecond laser spectroscopy

→ High harmonic and attoseond pulse generation

→ Electron streak camera and Auger decay







Acknowledgements

Time-resolved x-ray diffraction: **Klaus Sokolowsky-Tinten** *(Univ. Dusiburg-Essen)*

Atto-second spectroscopy: **Markus Drescher** *(Univ. Hamburg)*

H_2/Ru femtochemistry

Coworkers

S.Wagner, Ch. Frischkorn

Gd + TaS_2

Coworkers

L. Perfetti, M. Lisowski,

P. Loukakos, U. Bovensiepen

Collaborations

M. Rutkovski, H. Zacharias

Univ. Münster

A. Luntz, M. Persson

Univ. Odense/Liverpool

H. Berger

EPFL Lausanne

S. Biermann, A. Georges

Ecole Polytechnique, Palaiseau

Funding through DFG* (Sfb 450, SPP 1093, SPP 1133), *AvH, EU